AN ABSTRACT OF THE THESIS OF

Sarah E. Mikulak for the degree of Master of Science in Marine Resource Management presented on June 10, 2009.

Title: The Development And Evaluation Of An Interactive Exhibit To Support Real-Time Water Quality Data Interpretation By The Public At An Informal Education Setting

Abstract approved:

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Ocean observing groups are currently making efforts to work with well-defined end-user groups, like boaters and fishermen, to provide meaningful and effective real-time data (RTD) products and visualizations. However, providing meaningful data products for undefined groups such as the general public is not straightforward. In Oregon, several industry, science, and education organizations have formed a unique collaborative partnership to understand how to present and interpret water quality RTD to accomplish this goal. The project outlined here is the development of an interactive, computer-based exhibit, which interprets near-real time (NRT) data from Yaquina Bay as collected by a Land/Ocean Biogeochemical Observatory (LOBO), to facilitate the general public's understanding and analytical thinking about natural variability within an estuary and provide them with information that allows them to make more informed decisions about their environment.

Housed as a permanent exhibit at the Hatfield Marine Science Center Visitors Center, a free-choice learning facility, a prototype exhibit module composed of several levels of increasing complexity was developed to interpret salinity patterns using an iterative, formative evaluation process of unobtrusive observations and interviews to guide exhibit modifications and to increase engagement by the audience. Two versions of the exhibit were evaluated and visitor use was measured in three ways: 1) where they visited within the exhibit; 2) how much time they spent at the exhibit; and 3) types of talking that occurred during the use of the exhibit.

Findings reveal that visitors of all ages enjoy and understand the information presented in the exhibit, and that use of the exhibit and engagement in learning-indicative behaviors differs between social group types. Visitor use also changed in the direction that we were hoping from the first version to the second version; however, visitors did not engage with the NRT dataset online, which was one of the main goals of the exhibit. Because of this, we conclude that, whereas the easier levels of the exhibit are appropriate as an interactive educational tool to support visitor understanding of NRT data, the expectation that visitors at a free-choice learning facility will interact with the actual dataset, which is central in the harder levels of the exhibit, may be unrealistic. Recommendations for ocean observing entities interested in developing educational products for an informal, general public audience are outlined.

The Development And Evaluation Of An Interactive Exhibit To Support Real-Time Water Quality Data Interpretation By The Public At An Informal Education Setting

by
Sarah E. Mikulak

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

_____

Sarah E. Mikulak, Author

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CHAPTER 1: INTRODUCTION

The ocean is an expansive resource that is fundamentally important not just to those in direct contact with it, but to all life. Ocean scientists are constantly developing technologies to better monitor and understand the baseline characteristics of the ocean, as well as understand and predict any changes that may occur. This is especially important in the face of the numerous climatic and oceanic shifts that are currently taking place and the need to understand potential impacts of these on all aspects of life. In recent years, the data collected from these ocean monitoring instruments, which includes physical, chemical and biological characteristics of water as collected satellites, buoys, gliders, cabled arrays, etc., have been provided by the researchers or organizations that are collecting them for free online in real-time, near real-time or archived data formats for use by other scientists and other non-scientific sectors.

Real-time data, as defined by the United States Geological Survey (USGS), is "gathering information through periodic or continuous measurement in the field to provide a view of current conditions" (U.S. Geological Survey). This method of data collection and then subsequent presentation through an online format allows anyone to access information pertaining to the current status of a certain parameter is not just limited to ocean sciences. Some other applications of utilizing real-time data range from weather conditions from the National Weather Service or the Weather Channel to road hazard conditions from state transportation services. Real-time data implies that there is no delay between the moment of data collection and display. Near real-time data implies that there is either a delay between the time the data are collected and when the data can be accessed, or the data are not collected in an instantaneous, continuous manner. Some types of data need to be processed before being posted online, causing a delay, or they are only collected once an hour, day, week, or month and are therefore not instantaneous.

The use of oceanic real-time data is of top importance to scientists and managers as well as ocean dependent non-scientific commercial and recreation sectors, including fishers, boaters, surfers, and swimmers. Historically, research scientists have had to use labor, time, and money intensive methods to take measurements from a boat or run lengthy laboratory procedures on collected water samples in order to collect data, which was periodic at best depending in part of factors such as how often they were able to get boat time or limited personnel; this information only provided a snapshot of the conditions on that day at that time. Now, with the development of ocean observing technologies, scientists are able to deploy instruments that stay in the water for extended periods of time and deliver the data straight to the scientist's computer or, in some cases, a website. Depending on the type of instrument, these continuously deployed instruments offer users more of a panoramic snapshot of a slice of the ocean or a movie of sorts of the water flowing past the instrument. The increased resolution from these data collection techniques allows scientists to gain a more continuous and in-depth perspective of ocean characteristics and patterns and use the data to build various types of forecasting and backcasting models that are used by the other sectors.

Scientists are now working with managers and ocean users to develop models and methods of data dissemination that are best fits for their needs. The U.S. Integrated Ocean Observing System (IOOS), a program within the National Oceanic and Atmospheric Administration (NOAA), is a national coordinated system of agencies, people and instruments serving as a node for data collection of most ocean and Great Lakes observing organizations in the US, and facilitates the dissemination of these data in a meaningful way. IOOS has seven goals (National Oceanic and Atmospheric Administration, 2008):

- Improve predictions of climate change and weather and their effects on coastal communities and the nation
- Improve the safety and efficiency of maritime operations
- Allow more effective mitigation of the effects of natural hazards

- Improve national and homeland security
- Reduce public health risks
- Allow more effective protection and restoration of healthy coastal ecosystems
- Enable the sustained use of ocean and coastal resources

The regional IOOS organization in Oregon and Washington, the Northwest Association of Networked Ocean Observing Systems (NANOOS), has been working with several different user groups to support IOOS's vision of these seven goals in the Pacific Northwest. Managers in Oregon and Washington are currently using real-time data products to better inform their decisions about coastal fisheries, specifically when, where, and how much to harvest to protect human health safety levels from biotoxins in clams and mussels and to protect the ocean ecosystem to insure long-term health. Recreational and commercial tuna fishers off the coast of Oregon are now utilizing a sea surface temperature model developed by Oregon State University scientists as a decision making tool of when and where to fish since tuna are typically found in waters warmer than 59^{o}F, saving the fishers on gas and time. Real-time and modeled data of coastal currents are also useful to the US Coast Guard and others that are performing a rescue operation by providing a prediction of the path trajectory and inform their decision of where to focus efforts.

Besides these defined user groups, IOOS and NANOOS also state that they are providing these data to the general public, an undefined user group, as well, to support their understanding and decision making processes especially when involved with public management decision-making processes. A defined user group means a group that can be categorized and targeted to solicit feedback on data use and appropriateness of the dissemination methods (usability). An undefined user group is anyone else who is accessing the data for an unanticipated purpose, curiosity, for example. One venue to target this potential group of non-ocean dependant users is through the classroom.

NANOOS and other regional ocean observing organizations have been partnering with school teachers local to their area to develop activities and lesson plans to incorporate real-time data into the classroom. One of the more successful efforts of this has been achieved by Rutgers University through the development of their Coastal Ocean Observatory Laboratory (COOL) classroom website targeting middle and high school teachers and students. The Institute of Marine and Coastal Sciences at Rutgers in collaboration with the Jacques Cousteau National Estuarine Research Reserve, another program in NOAA, conducted a front-end investigation of needs for using real-time data in the classroom as identified by stakeholders in the observation organizations and middle and high school teachers (Parsons, 2006). Through collaboration with active teachers, both of these efforts identified general and specific needs of teachers, like aligning lessons with national science and math standards and the importance of inquiry-based activities, and have applied these lessons learned to their educational products.

Even though teachers and students may not be part of the ocean-dependant community, they are still a defined user groups with data needs that can be identified. A more difficult user group to understand is the public at large. These are the unknowns, with unknown motivations and reasons to access real-time data, unknown background understanding of the science and data visualization tools, and unknown uses for the data products provided by the observation organization. Without an understanding of the defined and clear use objectives of this nebulous group, the observing organization cannot create products or visualizations that meet the needs of that group. Outreach materials and information can be provided; however, the effectiveness of these are not known if the intended audience is not involved in the development process or targeted later for input on usability. If offered on a website, tracking cookies can be applied to track overall use, but motivations for use and overall effectiveness of communicating information is still unknown. So the questions these ocean observation groups are left with are a) who are these non-defined users

interested in real-time data, b) what is their knowledgebase, and c) what are they interested in interacting with?

We can start answering these questions with what we do know, which begins to answer b). Relative to the importance of the ocean on every American's life, the knowledge of this resource is not proportional. In one national survey of US citizens, only 14% of those surveyed reported as being "Informed" or "Very Informed" of ocean and marine related issues (Steel, Smith, Opsommer, Curiel, & Warner-Steel, 2005). In Oregon, surveys of adult residents and school-aged children indicated similar results to the national study, that there is generally low understanding of marine resource topics and functions (Steel, Lovrich, Lach, & Fomenko, 2005; Brody, 1996). Two national ocean policy reports, the Pew Ocean Commission report in 2003 (Pew Oceans Commission, May 2003) and the U.S. Commission on Ocean Policy report in 2004 (U.S. Commission on Ocean Policy, 2004), one regional report, the West Coast Governors' Agreement on Ocean Health in 2007 (The Office of the Governors Washington, Oregon, and California, 2008), and a local Environmental Monitoring of Yaquina Bay Meeting held in Newport, OR in 2006 (Heppell, 2006), all highlighted the crucial need for a more informed public. Both U.S. and Oregon coastal inhabitants have shown to be generally more knowledgeable about these topics because of the direct interaction, either through jobs, recreation, or environmental concern, whereas inland residents as well as women and those with a lower socioeconomic status, as determined by income, education level and occupation, exhibit lower levels of understanding (Steel et al., 2005a; Steel et al., 2005b).

Armed with the knowledge that, in general, the public's understanding of the ocean is low, the next question is where do people learn about the ocean? There are several possible avenues to present information about marine science and engage the public in these issues. Whereas we might commonly think of a formal classroom or job-training as the primary sources of scientific information, studies have found that a free-choice learning experience is the most important and frequently used method of learning science material (Falk & Dierking, 2002). Free-choice learning is a broad

concept that can be applied to multiple situations, but at its core is any learning experience that is self-motivated and any rewards gained are independent of the activity itself (Falk & Dierking, 2002). Many of these experiences occur during leisure time either in a designed informal education facility such as an aquarium or museum, or other situations including using the library or internet for self-motivated research. In these experiences, learning is a constructive process in which an individual builds on previously acquired knowledge that is mediated by social interaction and utilizes tools, such as a book, computer, or exhibit, to support the "cognitive activities" (Kim & Reeves, 2007) necessary for learning (Rowe & Wertsch, 2002; Kaptelinin & Cole, 2002). This theory, known as the theory of distributed cognition, has become a basic tenet in free-choice learning since most visitors visit a museum as part of a group (Falk & Dierking, 1992) and exhibits are an excellent example of a cognitive tool that supports higher thinking, such as problem solving, that might be unattainable for the individual without the tool (Kim & Reeves, 2007).

Because of the social nature of free-choice learning, these experiences are not just about incorporating new facts, but are also to re-affirm the self and the social bonds between individuals in a group through a mutually engaging activity (Falk & Dierking, 2002). Studies have shown that the public's interest in visiting science centers has been increasing over the past decade (Dierking, Luke, & Buchner, 2003) and that visiting Sea Grant websites, which are a fairly comprehensive resource for outreach materials, is correlated with a greater knowledge about marine resource issues (Steel et al., 2005a), which indicates the importance of learning science through free-choice learning avenues. This importance lends itself perfectly to initiate the process to develop answers to the other two questions posed previously about ocean observing data and the public: who are the non-defined users interested in real-time data and what type of format are they interested in interacting with?

This project is focused on attempting to answer these questions to mutually provide ocean observing groups a better insight of how to engage with the public and provide the public with a learning opportunity that supports their understanding of the

ocean. This was achieved through the development and evaluation process of an interactive, computer based exhibit with the design goals to be accessible to all ages and skill levels as well as be scientifically valid. There are a handful of exhibits that currently present real-time data in subjects that range from seismology (see *The Active Earth Display* developed by the Incorporated Research Institutions for Seismology) to space science (see the *CyberSpace Gallery* developed by the Adler Planetarium using NASA data) to physical oceanography (see *Seasons in the Sea* developed by the Seacoast Science Center in New Hampshire using regional ocean observing data), but the extent of the interactivity they afford allows the visitor to select the informational page they want to view, thus creating a one-way transmission of information that is similar to other types of outreach materials such as newsletters. Also, the research about the effectiveness of these types of displays is extremely limited, whereas research pertaining to the design and development of a more interactive and "minds-on" (Adams, Luke, & Moussouri, 2004) science exhibits in general is more extensive. The theories and design assumptions from these studies, as outlined in Chapter 3, were applied in this project to create a new type of real-time data exhibit to achieve the goals of understanding the following guiding questions for this study: are visitors at a science center an appropriate audience for real-time data? If so, what are the key elements necessary to facilitate the interaction with these datasets?

CHAPTER 2: EXHIBIT SETTING, GOALS, AND EVALUATION METHODS

This chapter will provide the overview and background of the project. The building blocks necessary for the initial stages of the exhibit, the exhibit setting, design team and goals, are outlined first. The methods of exhibit evaluation and data analysis are also presented.

Exhibit Location and Setting

The research for this thesis was conducted in the Hatfield Marine Science Center Visitor Center, located in Newport, OR. Newport is a city of 10,400 residents located on the Central Oregon coast with an economy based on commercial fishing, tourism, and wood products (Newport Chamber of Commerce). Newport provides residents and visitors several locations to engage in ocean-related free-choice learning, including interpretive centers at lighthouses, marine boat tours, the Oregon Coast Aquarium, and the Hatfield Marine Science Center (HMSC) Visitor Center (VC). HMSC was originally built in 1965 as Oregon State University's marine laboratory and has since expanded to include several state and federal natural resource management and research agencies, including Oregon Department of Fisheries and Wildlife, Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), and the United States Fish and Wildlife Service (USFWS), among others. The HMSC is located on Yaquina Bay one mile inland from the Pacific Ocean, which is an ideal location for researchers and managers to focus on both the open ocean and the estuary and conduct activities that are aligned with HMSC's mission:

> The Hatfield Marine Science Center is Oregon State University's campus for research, education, and outreach in marine and coastal sciences. Through its partnerships, HMSC improves scientific understanding of marine systems, coastal processes and resources, and

> applies this knowledge to social, economic, and environmental issues. (Oregon State University, 2006)

The HMSC VC is run by Oregon Sea Grant (OSG). OSG educators have been based at HMSC for close to 40 years and serves Oregon State University to support HMSC's mission of public research, education and outreach of marine resources. Education aimed at increasing the ocean literacy of all ages, from "cradle to grave", is a top priority for OSG, and is accomplished through several programs and resources offered through the VC to school groups and the general public. The VC offers visitors 15,421 square feet of exhibit space, a 160-seat auditorium and a bookstore. In addition, OSG oversees two running seawater laboratory classrooms with live animal tanks, a small, 'dry' classroom, and additional indoor space to hold live collections. The Free-choice Learning Initiative is a unique collaboration between OSG and the OSU College of Science that includes world-renowned researchers who utilize the VC as a social science laboratory to study how visitors learn in a place-based, informal sciences center that supports lifelong free-choice learning. The exhibits at the VC are designed to:

> 1) create a unique, dynamic environment for lifelong exploration and discovery;
> 2) encourage adults and children to enjoy marine science;
> 3) explain how scientific research enhances our ability to interpret the natural patterns that shape our world and enables us to better appreciate, manage, and sustain coastal and marine resources; and
> 4) provide opportunities for conducting research on devices, methods, and concepts for informal science education that will advance the art of public education (Oregon Sea Grant, 2007).

The exhibits, which include both interactives and live animals, feature current and on-going cutting-edge research being conducted by university and regional scientists. Many have been developed or evaluated through free-choice learning research conducted with visitors in the VC.

The VC, with a donation-only based admission, has about 150,000 general public visitors annually with an additional 12,000 K-12 students participating in other

OSG education activities. Previous studies conducted at the VC indicate that out of the adult visitors surveyed, between 60 to 80% are female and 55% to 65% of adults have at least their Bachelor's degree (Nickels, 2008). The US Census Bureau reports that 27% of US residents have attained at least a Bachelors degree (U.S. Census Bureau, 2009), so the visitors at the VC are more educated than that of the general public in the US. Existing studies have not been able to differentiate if these numbers are in fact true or due to a bias in visitors' willingness to participate in these studies; however, many studies including both random sampling and purposeful sampling have found similar results (Hodak, 2008; Nickels, 2008; Phipps, Rowe, & Cone, 2008). Roughly 30% of visitors are residents of the area with 70% having travelled from outside of the region or state, and around 50% of HMSC visitors also visit the Oregon Coast Aquarium during one calendar year (Nickels, 2008). The number of visitors to HMSC varies seasonally, with the majority of the annual visitors visiting during the key school spring break and summer vacation months of March, June, July and August as indicated by daily counts. Also of note is that the majority of visitors are part of a multi-generational group, and about 30% are part of an adult peer group; only a small percentage of visitors are individual adults (Nickels, 2008).

As mentioned before, the exhibits in the VC are based around the use of scientific research to explain natural patterns and to make well-informed management decisions. Many of the exhibits feature at least a few characteristics of successful family exhibits: multi-sided; allows for multiple users; accessible by both adults and children; allows for multiple learning outcomes; accessible by various learning styles and knowledge levels; easily understood text; and information is relevant to previous experiences and information learned (Borun, et al., 1998). Two of the most popular exhibits in the VC are the resident octopus tank and the touch tank; the regularly scheduled octopus feeding that occurs twice a week always draws a big crowd. Other exhibits based on previous or on-going research by HMSC scientists include topics about invasive species, oyster aquaculture, and marine geology.

The newest exhibition, *Rhythms of Our Coastal Waters*, is located in a 500 square foot room off to the side of the main floor and exhibition areas. In the past, the room has served as a location for temporary exhibits or a general resource room, but in response to a shift in marine science research trends to ocean observing systems, the focus and use of this room changed. The education administration and staff at Oregon Sea Grant are developing this room as a space for visitors to interact with data visualization systems, a process that began in late 2007. The centerpiece of this integrated data visualization resource room is a digital spherical display system (Magic Planet) exhibit, featuring animations of global oceanic and atmospheric data, with supporting flat-screen exhibits featuring regional and local oceanic or atmospheric data. The development of these spherical display systems as platforms for presenting ocean science data has been led by the National Oceanic and Atmospheric Administration (NOAA) At HMSC VC the exhibit consists of a three foot diameter Magic Planet connected directly to an interactive, touch screen kiosk that features an easy to use interface to explore various datasets.

For this thesis work, I developed a key component of the larger exhibition: an exhibit explaining local, estuary dynamics using real time data and developed to support understanding of regional and global data sets that will be exhibited on the Magic Planet. This interactive computer-based exhibit features a water quality dataset collected by Western Environmental Technologies Laboratories (WET Labs) using a Land-Ocean Biogeochemical Observatory (LOBO) system in Yaquina Bay which reports data hourly.

This vertically structured exhibit series (local-regional-global) has several goals. The overall goal of this room is to introduce several methods of data visualization, which include color contouring and false-color maps on the globe and flat screen, and line-graph time series on the local estuary exhibit. These data are derived from real-time, archived, and historical datasets, and, in turn serve as an introduction to the differences between these types of data. Even though the three exhibits would be able to used alone, they are being developed in conjunction with

each other to facilitate understanding of ocean and atmosphere patterns and the connections between all three focus areas (local-regional-global) both geographically and historically. Finally, the evaluation of these exhibits allows the *Rhythms of Our Coastal Waters* design and development team to understand what elements of these exhibits are necessary to support visitor understanding and use.

Exhibit Background

Exhibit Design Team

The design and development of the exhibit were executed principally by the author; however, many organizations played a part in supporting my design and development process. The idea of an exhibit was first developed through a partnership between WET Labs, OSG, and Oregon Coastal Ocean Observation System (OrCOOS). This section details the roles of each of these groups, and others, within the design and development process of this exhibit.

WET Labs, in cooperation with Satlantic, developed and deployed instrumentation in Yaquina Bay in Newport, OR that collects hourly water quality data that are updated in real-time online. The purpose for this data collection is for long-term estuary monitoring by WET Labs, university, agency, and other scientists, and for reference by the general public and other users. In order to reach and support the general public in their understanding of the dataset, WET Labs partnered with OSG and OrCOOS. The proximity as well as the expertise of the organizations were ideal for the formation of this partnership. WET Labs provided technical and scientific interpretation support, OSG provided educational and evaluation expertise, and OrCOOS was the initial scientific integrity support group. Later, the author also collaborated with other groups within these areas of expertise, including the science organizations NANOOS and the Center for Coastal Margin Observation and

Prediction (CMOP), and OSU students and faculty from the Science and Mathematics Education Department and the College of Oceanic and Atmospheric Sciences (COAS), specifically the Marine Resource Management (MRM) program.

The expertise included in the working group partnership of this exhibit was absolutely necessary for the implementation and completion of this project such that the result would be an effective and scientifically valid method of communication. Real-time datasets are large and, depending on the dataset, may be difficult for even seasoned scientists to understand or interpret at times. In order to make these datasets not only understandable to the general public, but to the general public in a science center where attention time may be much lower than at home, the dataset must be translated and organized in a way that is comprehensible by an diverse set of people. The data analysis from the science and technical groups -- WET Labs, OrCOOS, and NANOOS in this case -- are necessary if those in charge of the design and development are not trained in the necessary skills to interpret the dataset on their own. I was able to carry out data interpretation and use the science and technical teams as a method of checking for scientific integrity within the scientific content. The educational group – OSG specifically -- provided the design and guidelines within which the entire project would work best. The education and free-choice learning staff within OSG have a broad understanding of what types of elements would be the beginning point to an effective exhibit design; however, since using RTD in an interactive computer exhibit is very new, they only provided a general layout since there is not "tried and true" method for using scientific datasets in exhibits. During the development process, all parts of the working group were consulted by the author to check the scientific and written content, as well as the overall design and aesthetics and gather ideas of changes that could be made to the exhibit.

Data Visualization and LOBO

WET Labs, in partnership with Satlantic, Inc., developed the Land-Ocean Biogeochemical Observatory (LOBO), a long-term monitoring platform specific for estuaries and inland waters. The instrumentation includes sensors for temperature, salinity/conductivity, pressure, dissolved organics, chlorophyll, dissolved oxygen, and turbidity and includes anti-fouling measures for long-term deployment. LOBO observation systems have been deployed in six different locations around North America, including Yaquina Bay. In November 2007, WET Labs deployed LOBO in the Bay at 2m depth under a floating dock that moves up and down with the tide. LOBO collects data hourly, which is sent via cell phone connection as a data package to a main computer that unpacks it and posts it online to the LOBO website (http://yaquina.satlantic.com, Fig 1).

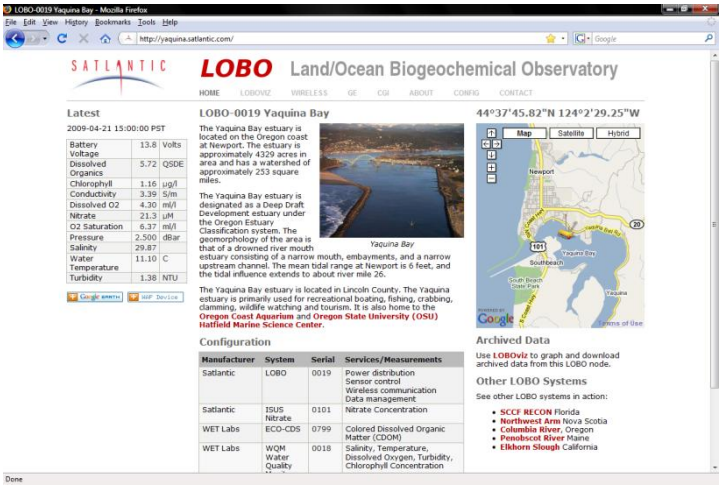


Figure 1. The main Yaquina Bay LOBO website.

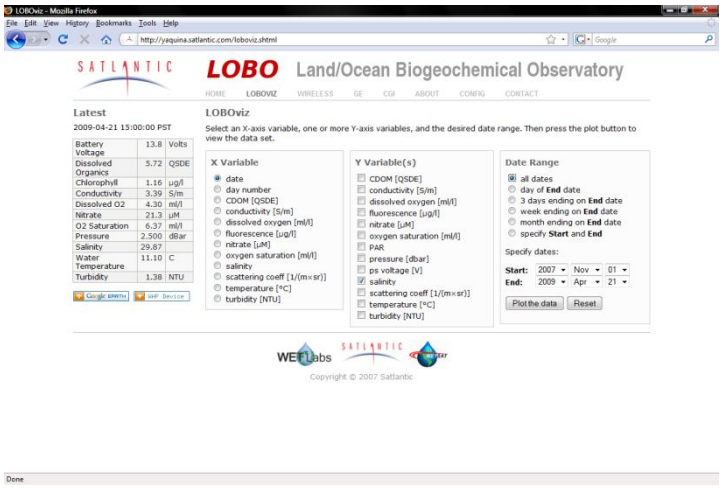


Figure 2. The graphing interface, LOBOViz.

LOBOViz is the software interface, designed by Satlantic, Inc., that allows the user to view collected data in a 2D graph. The graphing interface (http://yaquina.satlantic.com/loboviz.shtml) allows the user to choose the variables to be plotted on the X and Y axis, as well as the date range that they wish to view (Fig 2). LOBOViz is a powerful data visualization and display package capable of handling an entire network of monitoring sites. This simple web interface enables users to access and view real time or archived data, compare multiple sensors in customized time series plots, and compare data from multiple sites simultaneously. This real-time power gives system users rapid and easy access to the monitoring network to help make informed decisions. The data is presented in line graph format when plotted against time (Fig 3), and scatter plots when two data variables are plotted against each other. The data are also open source, meaning users are able to access the data used to plot their graph as text or download the dataset straight into Excel for their own personal use and analysis.

There are three possible constraints of this graphing software when considering its use by the general public. When graphed against time, the graphing program does not allow the user to define her or his own color for each variable, nor does it label the Y axis of what variable it is plotting. Also, the numerical range of the Y axis is auto-fit to each plot, so the user must be aware that they cannot directly compare plots without first inspecting the Y axis. This can lead to confusion and misinterpretation

since many variables with different units may be plotted together in one graph. For example, nitrate in the Yaquina Bay dataset ranges from 0-300 uM, and the dissolved oxygen range is roughly 2-8 ml/l. The resulting graph has a Y axis range of -50-350, which makes dissolved oxygen look artificially stable, an artifact which could lead novices to believe that dissolved oxygen does not change in the Bay (Fig 4).

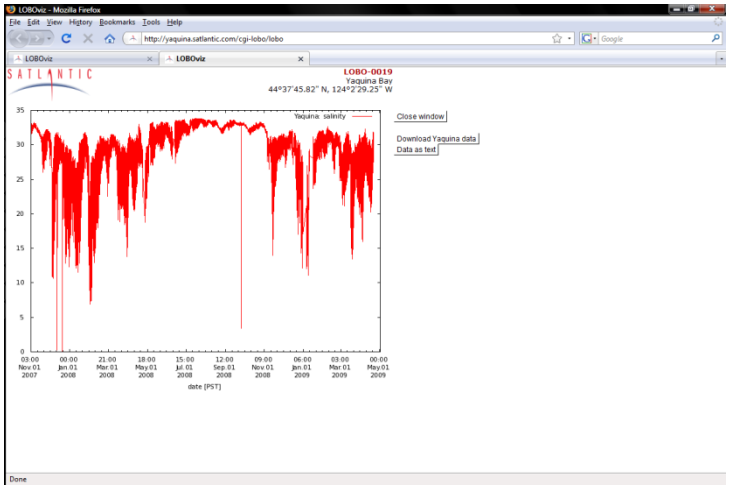


Figure 3. An example graph of all the archived data for one variable, salinity.

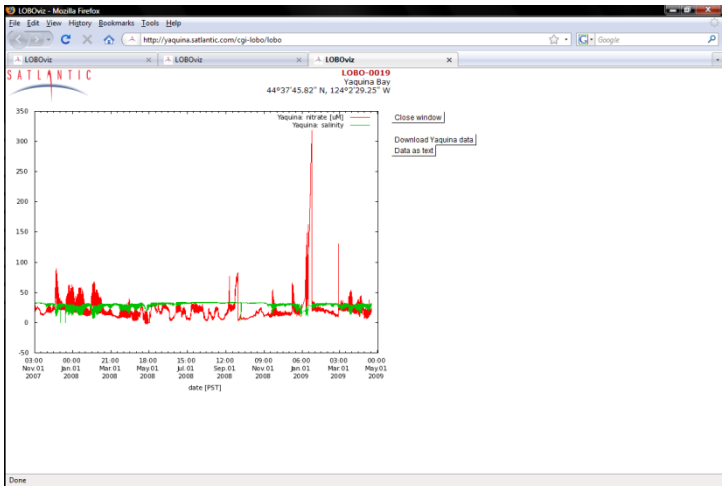


Figure 4. An example graph of all archived data for two variables, salinity and nitrate. Note how the y-axis range and line color for salinity changed from the graph in Figure 3.

Project Goals

As a part of the larger data visualization exhibit plan, there were three project goals for the local component. The first goal was to develop an interactive computer exhibit around data collected from Yaquina Bay and explain estuary dynamics. Initially this exhibit is to be a physical kiosk at HMSC, but the long-term view of this project is to also have it available online on the VC or OSG website since the exhibit is being developed for a computer and using a dataset available online.

The second goal was to understand what elements of an interactive exhibit are needed to increase meaningful visitor exploration of ocean observatory, real-time line graph data. The assumption at the start of this project was that not all but some visitors, given some background information and entertaining/engaging encouragement, would be interested in actually accessing and trying to interpret the data online themselves during their use of the exhibit at the VC. The ultimate vision from WET Labs is that LOBO's dataset would be accessed and utilized by the general public in a way similar to the way people check the weather. There is little to no supporting information that the general public themselves are interested in accessing ocean data for this purpose; however, many ocean observing groups hold this same assumption that at least some of the public will be interested in referring to these datasets once informed of their use and applicability.

Lastly, the most over-arching goal was to develop an entire exhibit model that can be used by other organizations and applied to other datasets. Using real-time oceanographic data in an interactive exhibit at a science center is so novel that there are no published studies or papers about effective exhibit models. The research for this project will provide a basic exhibit framework, the tools and methodologies, which can then be applied by other organizations to their own datasets with varying amounts of modifications, depending on the type of dataset. This goal was made at the onset of the project, and I did not anticipate reaching that goal during the time period of the project for the thesis; however, the most important component of this

project is developing the base methods that make up the core of the exhibit in a manner that is easily modified and replicable for other datasets and facilities.

Exhibit Objectives

Three main objectives drove the design. The technical objective was to introduce the technology that is collecting the data, the Land Ocean Biogeochemical Observatory (LOBO), and provide context for the importance of long-term monitoring data and collecting RTD in the Yaquina Bay estuary. The scientific objective was that the exhibit should assist and support visitor interpretation of the real-time data in either canned-graph or online graph form. Lastly, the education objective was for the exhibit to include multiple entry points, or many ways for a visitor to start interacting with the exhibit, to engage a broad audience. To achieve these objectives, a modular development process was employed by which one variable at a time that LOBO measures was presented so that lessons learned can be applied to the development process of subsequent modules. In general we expect the exhibit to provide an opportunity to become more informed and interested about RTD and water quality variations through direct interaction with these data.

Salinity

Since this project is starting as a true beginning point of understanding how to use and incorporate real-time scientific data into an exhibit designed for use by the general public in a informal science learning setting, I decided with the support of the exhibit working group to start first with what we believed would be the easiest variable, salinity. Out of all the other variables, this was the easiest for the exhibit to explain, since it was assumed that most visitors have heard of salinity before or would be able to readily understand the concept. Salinity as a variable is easy to explain,

how much salt is in the water, and the factors that cause changes to the salinity are not complex, increased rainfall and river discharge and low tide cause the salinity to be low, and increased ocean influence and high tide cause the salinity to be high, and are concrete ideas that most visitors could readily visualize and understand. An estuary is a highly dynamic environment because of the ocean and river inputs, so salinity not only changes from day to day, but moment to moment. Using salinity, we can get a fairly good idea of the origin of the majority of the water in the Bay, which is an indicator of the changes in the other variables that we would expect to see and what state we should expect the habitat to be in. Since salinity is acting as our ecosystem indicator as the base of the ecosystem, it is important as well to lay down a good background and foster understanding of one of the important drivers in this ecosystem.

Evaluation Methods

All the materials presented as part of the exhibit, four posters and a computer component, were evaluated using observations and interviews. Evaluation of the exhibit was performed three times: the first during February 2008, the second during late August to mid-September 2008, and the final from mid-February to mid-March 2009.

Round 1

The first round focused partly on the development of the final versions of the posters with some preliminary observations of the computer component. Three audiences were targeted for feedback on the content, overall look, and ease of interpretation of the posters: technical and scientific researchers that are part of the working group; VC visitors; oceanography and marine resource management graduate students and professors. The feedback from all of these different groups was

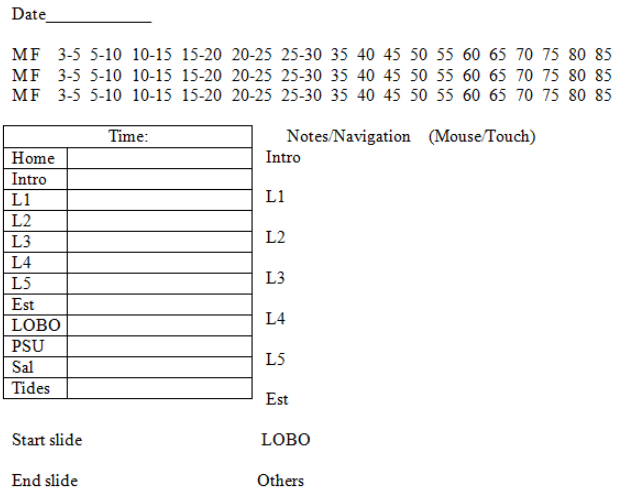
invaluable since each audience provided different insights: visitors were only asked to give information related to what they liked or didn't like, whereas the researchers or students in the field offered alternate ideas of how to present the information or other modifications to make, which was much more useful for the design process. To evaluate visitor use, the posters were hung in the VC during two weekends, and visitors who walked into the room or were just on the outside of the door were invited by the researcher to read and view the posters to assist with ongoing, exhibit development research. Upon the visitor's exit visitors were asked what they liked about the posters, if there was anything they didn't like or understand, and if there were any changes that they would like to see made. These comments were taken into consideration and incorporated into revisions as necessary. The third group, graduate students and researchers in oceanography and marine resource management disciplines, were invited to post comments on the four posters while they hang on a cork board in the hallway for one week.

Two groups were observed using Version 1 (V1.0) of the computer component during this round. The first group was non-targeted visitors at the VC and the second was a Communicating Ocean Sciences class for graduate students. For two weekends in February the computer component of the exhibit was on display along with the posters. The observations conducted at the VC for this round took place over three weekends, the first one dedicated to poster evaluation only, the second was for both computer and poster evaluation, and the third was computer evaluation only. During this first computer evaluation round, the computer was a Dell desktop with a non-touch, flat screen monitor that only allowed visitor interaction through a mouse. The second group was a targeted observation of a class composed of pre-service science and math teaching students as well as master's students in the marine or environmental sciences fields. The computer component was projected so that the entire class could see it, and one of the students navigated around while the class gave input of where to go in the exhibit or comments and questions directed at the researcher. Changes were incorporated to create Version 2 (V2.0) of the computer component based on these

observations, as well as feedback from the working group and from attendees at the Ocean Sciences 2008 meeting where the work on this project to date was presented (Dr. Cynthia Cudeback had the initial idea that inspired the new design of Level 1 for V2.0 as described in Chapter 3).

Rounds 2 and 3

The last two rounds of exhibit evaluation were focused on visitor use of the computer component, as presented on a touch screen monitor, and share similar methods. Round two, which evaluated V2.0 of the computer exhibit, was conducted during August and September, 2008. Round three, which evaluated Version 3 (V3.0) of the computer component, was conducted during February and March, 2009. During each evaluation round, 73 visitor groups were observed using the exhibit. A preliminary observation period was conducted before Round two in August, 2008 to pilot the data recording tool and determine common actions and behaviors to be coded during observations (Fig 5).


Date_____

M F 3-5 5-10 10-15 15-20 20-25 25-30 35 40 45 50 55 60 65 70 75 80 85
M F 3-5 5-10 10-15 15-20 20-25 25-30 35 40 45 50 55 60 65 70 75 80 85
M F 3-5 5-10 10-15 15-20 20-25 25-30 35 40 45 50 55 60 65 70 75 80 85

Time:	
Home	
Intro	
L1	
L2	
L3	
L4	
L5	
Est	
LOBO	
PSU	
Sal	
Tides	

Notes/Navigation (Mouse/Touch)

Intro

L1

L2

L3

L4

L5

Est

Start slide

LOBO

End slide

Others

Figure 5. Observation data recording tool. Gender and approximate age of each visitor were recorded at the top. Time spent within each level or informational page was recorded on the left, and notes of actions and talk engaged in were recorded on the right.

In addition to observations, interviews were conducted with visitors who interacted with the exhibit for four or more minutes. Four minutes was determined as the cutoff based on observations in piloting that this was roughly the amount of time taken by visitors who went through the majority or all of at least one of the levels. The goal of the observations was to record and understand the use patterns for the exhibit as well as ascertain the most common navigation paths through the exhibit and in which level the most visitor time was spent. The goal of the interviews was to gather more specific feedback from visitors who used the exhibit for a significant amount of time.

Observation data included recording gender and five or ten year age range of the visitor interacting directly with the computer as well as all the individuals in their associated social group, time spent at each level in the exhibit, the order of navigation between levels, and coded actions and behaviors. The individual demographics for each group that interacted with the exhibit were then coded within three different categories:

- Group gender: Female, Male, or Mix gender
- Group size: Number of visitors in the group
- Group Type: Individual Child, Teen, or Adult; Peer Children, Teens, or Adults; Multi-generational group (family-type)

To record time and navigation, a stopwatch was started as soon as the visitor first touched or clicked in the exhibit, and the time at which they navigated to a new level was recorded, keeping a continuous measurement of time. The end time was recorded, and the time spent in specific levels was later calculated and the navigation path was determined based on the times recorded for each level.

The following actions were coded and recorded during the observation:

- Interaction method: mouse or touch screen
- Sitting at stool in front of computer
- Read out loud

- Point at the screen or graphs
- Join or leave the group
- At least one of the members of the group is looking over a shoulder

The slide or text being read out loud was specified in observation notes, and any other types of conversations or dialogue between social group members were written down in as much detail as possible. These conversations were then coded into one of three categories: an adult and child have a question and answer dialogue; at least two peers have a question and answer dialogue; and the social group has a conversation that didn't start as a result of a question.

Visitors who interacted with the computer component for longer than four minutes were asked to participate in a short interview after they completed their interaction. The interview, which was conducted within ten minutes of the end of the visitor's or group's usage of the exhibit, was composed of the following questions:

- Where there any parts or elements of the exhibit that made it easy to navigate or understand?
- Where there any parts or elements of the exhibit that were challenging to navigate or understand?
- Did you learn/get anything out of/take anything new away from the exhibit?

Follow up questions or statements were sometimes asked for clarification. These answers were then also recorded in the notes section of the datasheet for that group.

Even though the evaluation methods between the two rounds are similar, the results are used in slightly different ways. For this thesis, Round 2 was viewed as the formative evaluation round and Round 3 as the summative evaluation round. The challenges observed, time spent, navigation routes, and interview comment results from Round 2 shaped the changes made to produce Version 3 of the computer component.

Data Analysis

Visitor demographics, group size and group type, were recoded for analysis to have usable sample sizes and to make comparisons more meaningful. Group sizes of one or two were maintained as Individuals or Pairs, but any groups larger than two were placed in the category Groups of 3 or more. For group types, the original categories of Individual Adult and Multi-generational group was maintained, but individual children and teens were collapsed into Individual Youth, and the age distinction was removed from all peer groups creating one Peer group category.

Where a user visits in the exhibit is measured two ways: the place of their first visit (First Visit), and the zones visited during their entire time of use (Total Visits). The levels of the exhibit are grouped into four major zones: Intro, which is the home and two Intro pages; Info, which consists of the estuary and LOBO pages; Easy, which is made up of the two levels in the first column on the second Intro page, Levels 1 and 2; and Hard, which is made up of the three levels in the second column on the second intro page, Levels 3, 4, and 5. The visitors included in this analysis are ones that started with the home page and subsequently visited the intro pages; visitors that started their interaction somewhere other than the home page are in the minority and are not part of the most common navigation route through the exhibit, and are excluded in further analysis.

Total time spent at the exhibit was coded into three categories, 0 to 1 minute, 1 to 4 minute, and more than 4 minutes. The 1 minute cutoff was determined from literature, which is the upper most boundary of the average time visitors spend at exhibits on the whole, and the 4 minute cutoff was carried over from the evaluation interview time cutoff.

Types of visitor talking was categorized into reading out-loud, asking a question, making a statement, and any type of talk to understand how many unique groups were observed engaged in at least one type of talk. Each unique type of talking, reading or making a question or statement was counted once for each group. Reading out-loud was where any text was read verbatim from the exhibit slides. Asking a question ranged from asking a clarifying question to a peer, or asking a

leading question to a child, and sometimes led to a discussion between visitors. This subsequent discussion was started by a question and therefore is still coded under question since it was a question initiated discussion. Under the statement made category, any discussions that were not initiated by a question were placed under this category. Since many groups engaged in many different types of talking, the any type of talk category was to determine how many groups engaged in at least one type of talking. To measure the complexity of talk occurring, groups were also coded into how many different types of talking they engaged in: none, one, two, or three.

The Chi-square test was used to compare groups between evaluation rounds, and types of exhibit uses, like visit zones, time spent, and talking. Group size and group type were compared between evaluation rounds, first and total visit zones, and total time spent at the exhibit. The test was also used to determine difference in use between evaluation rounds, and also if groups in different visit zones spent different amounts of time at the exhibit.

CHAPTER 3: EXHIBIT DESIGN AND DEVELOPMENT

Exhibit Design Theory

The three original groups involved in this project, WET Labs, OrCOOS, and Oregon Sea Grant, determined that the best method of disseminating the information they are interested in was through a physical exhibit to be housed at the HMSC Visitors Center since its use and the behaviors of the users could be carefully evaluated. The exciting challenge of designing educational tools for informal education facilities is that visitors come in with various motivations, interests, and previous knowledge (Falk & Adelman, 2003; Falk & Storksdieck, 2005). A variety of traditions in psychology and learning sciences have converged on the basic idea that people do not engage in activities that do not meet their interests, or present information or an activity that is too challenging (Falk & Dierking, 2002; Rowe & Wertsch, 2002; Lewin, 1935). The following is an overview of how works like Csikszentmihalyi's (1991) concept of flow, Vygotsky's zone of proximal development (1987), and Lewin's (1935) Level of aspiration were applied to the design and development of the exhibit to communicate information about real-time oceanographic data to the public and shape the design and evaluation process of this exhibit.

Cognitive tools

As mentioned in the introduction, a socio-cultural approach to learning explains how social groups and cognitive tools mediate the action of learning such that all knowledge is then distributed between those cognitive tools and social groups (Rowe & Wertsch, 2002; Kaptelinin & Cole, 2002). Cognitive tools, as defined by Vygotsky, are a socially meaningful meditational means for cultural development,

and, depending on the interpretation, ranges from language to cultural routines to physical objects, such as buttons found on technology (Rowe & Wertsch, 2002). However, utilizing and thinking about computers as cognitive tools is challenging because cognitive tools are not passive communication systems that present information, but rather are ways of supporting higher-order thinking, as when users make sense of information (Harper, Hedberg, Corderoy, & Wright, 2000; Kim & Reeves, 2007). Computers have been advanced as particularly useful platforms for learning in that they allow for practice using particular cognitive tools in relatively low-stakes environments such as games. It is for this reason that pilots practice initially on flight simulators and nurses practice working with patients on-line in Second Life. The computer itself in both of these examples is not a cognitive tool. Instead, it is a something like a learning environment of context that supports the use of well known and new cognitive tools by users. Particularly when the user is a novice in the field, learning activities that provide for the scaffolded use of cognitive tools support engagement in "authentic tasks" (Kim & Reeves, 2007) of that field even if the learner has only a cursory knowledge of the skills and language used in that community (Harper, Hedberg, Corderoy, & Wright, 2000). Because we are assuming that the majority of visitors in a public science center do not have the skills necessary to complete the kind of advanced data analysis that is commonplace for oceanographers, we need to start with an exhibit design that is user-centered and easy to understand and that will ultimately scaffold participation and use of novel cognitive tools.

User-centered design

User-centered design is a concept that can be applied to a whole host of different types of products. For exhibits, user-centered design means that the exhibit takes advantage of what the visitor instinctively knows how to use (buttons are for

pushing), whereas for computer interface design it is more focused on understanding the needs of the user to provide appropriate tasks, tools and interfaces to reduce the cognitive load necessary to just understand how to use the program (Allen, 2004; Soloway, Guzdial, & Hay, 1994). In this project we are focused on combining these two meanings by designing a computer interface that is salient and intuitive for any person to use regardless of their experience of using computers.

Goal-based scenarios

Where the interface of the computer exhibit should not require high levels of cognition, the learning tool that the interface allows the learner to interact with should support the various interests and goals of a multitude of learners. Because of the diversity in underlying visitor motivations and goals at a museum (Nickels, 2008), we structured the exhibit in several, progressively more challenging levels, each with a different type of end goal. This type of design, based loosely on Schank et al.'s (1993/1994) goal-based scenarios, allows the learner to develop and pursue their own learning goal, instead of interacting with instructor imposed learning goals. According to Schank et al., this type of curriculum design is more in line with what we would call free-choice learning since the learner participates in what interests them. Implementing goal-based scenario design in an exhibit creates multiple entry points and goals for visitors to interact with, allowing the visitor to enter and exit exhibit interaction while still achieving a sub-goal, if not the ultimate goal, of the exhibit and is consistent with the characteristics of family-friendly exhibits (Borun & Dristas, 1997).

Scaffolding

The goals of this exhibit are a realization of the conceptual steps of the process that scientists, as experts in their field, use to interpret data. Within each sub-goal of the exhibit related to this larger goal is a level of scaffolding so that a non-expert can have a meaningful interaction with the exhibit. Scaffolding is much like tutoring in that support, such as leading questions, hints, or modeling, is provided to the learner was necessary to enable them to successfully complete the activity (Wood & Wood, 1996; Wood, 2001; Quintana, et al., 2004). Judging the appropriate time to step in with these scaffolding techniques is sometimes difficult in a human-to-human interaction (Wood, 2001); programming it into a computer program can be even more difficult. Some programs can be designed with Artificial Intelligence that adapts responses to specific user inputs, such as many "help" features within software packages. But at its most basic, scaffolding in computer systems can be as simple as feedback acknowledging a correct answer or providing more information to assist the thought process if the wrong answer is provided to a prompt (Azevedo, Cromley, & Seibert, 2004). Another key element in scaffolding is fading, or reducing the level of support as the learner shows proficiency in the activities (Wood & Wood, 1996). Fading is an important element of scaffolding in that it allows the learner to progressively take control of the learning situation and become practiced in the use of the cognitive tools that are being mastered. Fading was built in to the exhibit design in the sense that a great deal of scaffolding was built into lower levels of the program with scaffolding fading to almost zero in the highest level of interaction. In all, scaffolding allows the learner to participate in activities and practice skills that experts utilize in a way that is not threatening and encourages shared learning experiences within a social group (Gobet & Wood, 1999; Mercer, Dawes, Wegerif, & Sams, 2004; Quintana, et al., 2004).

Design-based research and Formative evaluation

Lastly, the principles of design-based research from engineering and technology fields and formative evaluation from the informal education field shaped how this study was implemented. Design-based research is a process used to test design assumptions and theories of the learning tool in this case, and understand the common uses of the tool by learners (Wang & Hannafin, 2005). This process ranges from projects that are completely theory driven to projects that are designed based on user input and comments with no backing theory, but at the core all design-based research projects with exhibits contain the same end-goal: to test how the exhibit is used and if that use fits within the desired or anticipated use (Wang & Hannafin, 2005). If not, changes can be made to the design and elements in the exhibit to encourage or change the use patterns into what the designers were anticipating. This monitoring and research of use in the informal education field is generally referred to as formative evaluation. As in engineering fields, effective exhibit designs are achieved based on a prototyping process that utilizes observation and/or interview techniques to record and understand visitor use (Allen, 2004; Borun, et al., 1998). Formative evaluation is the process undertaken when the exhibit is still under development but closely resembles the finished product and allows the researcher to make the necessary changes to the exhibit before it is made into its final form; in comparison, a summative evaluation is used to determine the overall impact of the final product of the exhibit on visitors (Diamond, 1999). This research is achieved through multiple recording techniques to understand visitor use, including observations, interviews, surveys, or other types of learning assessments (Diamond, 1999). In this project, Frank Oppenheimer's (previous director of the Exploratorium in San Francisco) philosophy of "people will learn what they want and when they want and what visitors learn is less important that the fact that they learn something" (Bitgood, 2002, p. 465) is generally adopted, so the specific information that people learn while interacting with the exhibit is secondary to how visitors interact with it as a learning tool from the researcher's perspective. Because of this, the formative evaluation methods utilized in this project are unobtrusive, detail recording

observations and informal interviews of visitors that spend a longer amount of time at the exhibit. For this type of evaluation, 40-60 groups are recommended as an ideal sample size (Diamond, 1999).

Exhibit Component Goals and Design

The initial exhibit design concept developed by the working group at the beginning of the project was followed very closely to the completed evaluation stage of the exhibit. The exhibit itself is composed of four 2'x3' passive text posters and computer station composed of a Shuttle Glamour G5 computer and Elo TouchSystems 17" touch screen monitor. For both stages of the evaluation, the monitor was on a low counter with stools in front of it with the posters displayed within close proximity of the monitor. This section is an overview of the goals with which each of these was created and what the final version that was used during the computer evaluation rounds were used. The revisions made to both the posters and the computer component are expanded upon in a later section.

Posters

The four posters were used as background and supporting information to the data on the computer as well as one type of entry point. Each poster focused on one theme. The goal of the *Rhythms Of Our Coastal Waters* poster was to introduce the Yaquina Bay estuary, why it is an important habitat, and two predictable rhythms in estuaries that change the salinity, tides and seasons. The goal of the salinity poster, entitled *Rhythms Of the Seasons: Can we tell the season both above and below the water?* was to introduce the differences between the seasons both above and below the water of the estuary and the factors at play that cause changes in the salinity seasonally. The goal of the *LOBO: The Land-Ocean Based Observatory- Measuring*

Rhythms of Yaquina Bay with Bio-geophysical-chemistry poster was to introduce the visitor to the instrumentation that is collecting the data from the Bay and the variables that it collects. The goal of the poster entitled *Why is this data being collected?* was to inform the visitor of the reasons behind collecting the data and the importance of having long-term, ocean monitoring datasets as well as to briefly explain the importance of ocean habitats.

Computer component

The computer component is the main feature of the exhibit and focus of the majority of the research in this project. The majority of the project and exhibit goals relate to the computer component, and even though the posters are utilized and developed to be another type of entry point, they are only supporting materials to the information presented on the computer. The specific objective of the computer component was to support visitor understanding of real-time oceanographic data to facilitate the usage of the online dataset. This overall objective was supported by several design factors, including the use of familiar and intuitive navigation tools, specifically a touch screen monitor and a previously evaluated exhibit interface design, and a design format of scaffolded, goal-based scenarios laid out in five levels of increasing difficultly/scaffolding fading, which allows the visitor to choose what level of difficulty they want to interact with.

Touch screen monitor

One of the design tools that are used in the exhibit is a touch screen monitor. The touch screen allowed for a fairly novel/interesting way for the visitors to interact with the exhibit interface, and is probably a method that is more expected by visitors at a science center than using a mouse. However, a mouse was still provided for visitor use as an alternate method of interaction if they are more comfortable with that

method and also because the online graphing interface featured small boxes to select that may be too small for visitor selection by touch alone. If this were not the case and the website was designed in such a way that was appropriate for navigation by touch alone, a mouse would not have been included at the exhibit.

Computer exhibit interface

The exhibit interface on the computer is modeled after an exhibit layout previously evaluated at the VC and was developed using PowerPoint 2007 (Smith, 2007). PowerPoint provided a great deal of flexibility and affordances in creating a polished looking, interactive exhibit without having any programming or computer design background. The navigation between slides is accomplished by hyperlinking action buttons to specific slides and running the presentation in Kiosk Mode so that the only navigation that can occur is through selecting buttons that have hyperlinks and not progress to another slide by an errant touch of the slide itself. Because of the nature of the program used for the development of the exhibit as well as the nature of the exhibits overall design, the exhibit is not adaptive to the visitors' inputs, like many scaffolded computer learning environments (Azevedo, Cromley, & Seibert, 2004) and the navigation paths were set, but are designed in a way to scaffold visitor inputs in the easier, more scaffolded levels.

For all the exhibit slides, except for three slides, the Home and Introduction slides, the layout of the interface was consistent (Fig 6). A title bar indicating the title of the level the visitor was in is located at the top, and a navigation bar where buttons linked to the first slide of each of the five levels as well as an additional information page is located on the left-hand side. The side navigation buttons were labeled with the title of level plus an additional quality indicating in some way the difficulty level of each level. Each page, again except for the first three slides, included a home and back button, which was either linked directly to one page or to last page viewed if multiple slides linked to that particular slide, in the lower right hand corner. This left

the majority of each slide open as the "working area" in which the content of the slide was contained. During the development process, consistency of color usage, shapes, text font and size, and textbox, action button, image and graph size and placement was maintained throughout the entire exhibit.

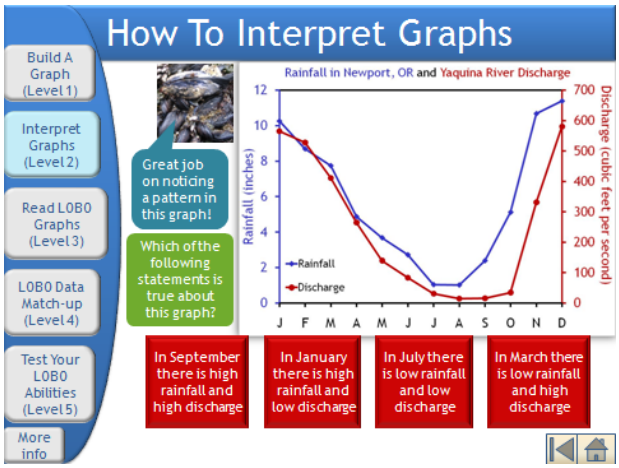


Figure 6. Example exhibit screenshot from V3.0. The title bar at the top, navigation bar and buttons on the left, and back and home buttons on the bottom right were consistent on all pages in the exhibit except the Home and Intro pages.

Computer exhibit levels

The design of the five different levels in the computer component was loosely an application of scaffolding and goal-based scenarios. The details of how scaffolding was operationalized in each level is explained in more detail below; however, the idea of fading the intensity and amount of scaffolding was applied to the five levels as a whole: Level 1 has the greatest amount of scaffolding, and the scaffolding fades as the levels increase up to Level 5, which has no scaffolding. Theoretically, goal-based scenario training or education is an adaptive computer program which allows the learner to choose their own learning goal to seek within the program. The exhibit,

though not adaptive, still allows the user to choose which out of five goals they want to pursue. The exhibit is not a pure representation of goal-based scenario learning since the goals were chosen by the working group during the design and development process and were based on anecdotes of limited previous research and conjecture. The evaluation process allowed the researcher to understand if the conjectures of what type of goals the visitors are interested in pursuing were indeed the correct ones, and in some cases resulted in a change in goals that were originally decided on and developed. This process also allows the visitor, though unknowingly, to have a say in whether they were interested in the goals presented or not.

Home and Intro pages

The Home page is by default the first slide of the exhibit and is the entry point into the computer component of the exhibit. Depending on the computer version, one to several buttons allows the user to access any of the following slides in the exhibit. The Intro pages were added for V2.0 and maintained in V3.0 and featured background text briefly explaining the data and the purpose of the exhibit. On the first Intro page, there were buttons to the Estuary and LOBO Info pages, and on the second Intro page there were five navigation buttons, each linked to one of the levels in the exhibit. These pages are highly important since they not only provide a general background to the exhibit but also a first impression to visitors. This first impression proved to be highly influential to visitor use, as discussed in the two Findings chapters.

Level 1: How to build a graph

Being the first level, Level 1 is the most basic in concepts and explanations. The goal of this level is to introduce the visitor to how a line graph is built, what the main features of a graph are, and how to interpret a line graph that has one data point per month.

Final design for this was an interactive salinity scale where the visitor selected along the line of 0 to 40 PSU the average salinity for the following: the Pacific Ocean during the entire year, Yaquina Bay during the entire year, Yaquina Bay during the winter, and Yaquina Bay during the summer. After this introduction activity to the differences in salinity between the two connected bodies of water and seasons within the Bay, a series of step-wise animations illustrates how a graph is made up of two axes and how data is plotted, with some companion statements that point out important features in the data. The data used in the graph building segment was a monthly averaged salinity data recorded by LOBO from September 2006 to January 2007 and May 2007 to July 2008.

The first segment of the level is scaffolded with responses indicating correct or incorrectness with a short, one sentence blurb about the correct answer. The second segment is not scaffolding in the pure sense that the exhibit responds to the visitors' inputs, since there are no questions asked. However, it is full of important information that may be very basic for some, but may be novel information for others, and so it is scaffolding for the entire exhibit.

Level 2: How to interpret rainfall, discharge, and salinity graphs

Level 2 assumes that the visitor understands how to read graphs and provides the visitor their first chance to test their graph interpretation skills. There are two sections within the level: the first is centered around graphs depicting the relationship between rainfall in Newport, OR and the river discharge of Yaquina Bay at Chitwood, OR; the second uses a graph to depict the relationship between rainfall and the salinity of Yaquina Bay. Rainfall is very seasonal in western Oregon, and is one of the major drivers in the change in river discharge and decreased salinity in the winter. In this level, all the data were presented in monthly-averaged graphs, so one data point per month. The historical rainfall data were from the HMSC weather station weighed rain gauge and the historical discharge data were from USGS, as collected from 1971-

1991. All of the seasonal relationships are apparent in the monthly averaged graphs and because seasonality is a relatively easy concept to explain on the development side of things as well as understand from the user's point of view, this was the focus of this level. The concepts focused on are a) how many seasons occur in the Bay b) what time of the year they occur and c) is the variable high or low relative to the other variables during summer and winter. The way seasonality of each of the variables is explained is in relation to the amount of rainfall - since rainfall is seen and understood, the relationship to discharge is then made - the high amounts of rain during the winter leads to high amounts of discharge during the winter, which then leads to low salinity during the summer.

Each section in this level is set up in a similar manner in a multiple choice format with question prompts for the visitor to answer by selecting one of up to four buttons with possible answers on them. The two sections start with an introductory question asking if they understand the graph they are looking at. If the visitor answers yes, then they proceed straight to the next question; but if the visitor answers no, then they view two slides that point out the major features and relationships that the graphs are showing before moving on to the first question. When presented with one of the multiple choice questions, if answered correctly, the visitor gets congratulated and is presented with a short blurb of why the answer is correct. If incorrect, the visitor is presented with a "Not quite" response and some text supporting text to help the visitor look at the correct area of the graph or support the visitors' understanding of what the question was asking and understanding of the concepts that are presented. There are several of these incorrect response steps before the visitor gets taken back to the beginning of the section to orient them to the graphs. The last question in each section is a different type of graph, two one month, daily data graphs, one from the winter and one from the summer. In the first section the graph is of the daily rainfall reported by HMSC, and in the second section the graph is of daily average salinity data from the Bay. The visitors are prompted to select the graph that is from either summer or winter.

The scaffolding in this level is very high, though it is designed that visitors will encounter it after an incorrect input. Unlike Level 1, which spells everything out for the user, assistance with information in Level 2 only appears when the correct answer is not selected. In this way, the fading is implicit in the design of the exhibit since less help or hints are offered to the visitors who have a better understanding of the material or relationships and can answer more correct answers- offering a challenge but not something too difficult. However, those users who are still novices to reading graphs or understanding the relationships between these variables have supporting information and hints when necessary, hopefully lessening the user's frustration of not having enough information or having too much.

Level 3: How to read/interpret real-time data graphs

The goal of Level 3 is to make the transition from reading and interpreting canned or historical monthly averaged graphs to reading and interpreting RTD graphs accessed from LOBO's website. The design for this level starts with familiar monthly averaged salinity graphs, and introduces daily averaged and then hourly data through a series graphs, while highlighting important features and prompting the visitor to think about factors that cause salinity changes seen in the graphs. This level begins with the seasonal patterns already discussed in Level 2 and introduces the variation of salinity within the seasons when more data points are included with the daily averaged graphs. When hourly data graphs are introduced, the concept of how high and low tide affects salinity is introduced.

The design of this level is to make the visitor less dependent on being given the correct answer and promote conversation within a group of visitors using the exhibit together. Every slide has a question prompt for the visitor to contemplate about the graph before they move on to the next slide. Some of the questions are then answered on the next slide or the visitor can access a slide that shows the answer, but some are not answered. The scaffolding is faded because there the program does not check or

monitor the visitors' answers through input. Therefore, this level is self-regulated by the visitor. The open-ended nature of the questions in this level models types of questions that visitors can ask themselves when viewing RTD online and highlights some of the important features, such as storms during the winter and the constant salinity conditions that are common during the summer months. When questions are answered, they assist the user with interpreting the graph, which allows the user to verify their answer.

Level 4: Investigating rhythms using real-time data or Rainfall and salinity match-up challenge

The goal of Level 4 is to introduce the visitor to interacting with RTD graphs accessed directly from the LOBO website through structured and direct instructions. The title change of this level from V2.0 to V3.0 is reflected in the title of this section. This level represents an advance in the expectations of the general user. For example, no RT salinity data were manipulated or processed to be made into graphs for this level; all salinity graphs were made using data graphed directly from the LOBO website. Level 4 assumes that if visitors had walked through some or all of the previous levels, or start at this level because they already have the background information provided by Levels 1-3 provided, they would be able to look at a RTD graph and be able to answer simple questions related to how the weather during that time period changed the salinity. This level was to test a user's understanding of reading the type of graphs that the LOBO website produces as well as their understanding of what information the graph is actually telling them. Little to no scaffolding is present, depending on the version of the exhibit, so visitors at this point have little to no feedback from the exhibit about their performance or understanding, it is now up to the social group that they are a part of, if they are, to scaffold and support the learning process.

Level 5: Discover Yaquina Bay's salinity story in real-time data

The goal and intention of Level 5 is similar to Level 4 in that it also instructs the user to interact with the RTD graphs accessed from the LOBO website. The difference is that the instructions for this level are not as structured as Level 4, with the intent to encourage a more exploratory interaction with the data. This level is the final level that requires an extensive knowledge and skill set to interpret the dataset that is accessed online. There is no scaffolding in the exhibit since this is an exploratory exercise which will be different for each user or user group.

Info pages

The Info pages were added to V2.0 and maintained in V3.0 to provide the user with more background context for the Learning Levels, or Levels 1-5, in the exhibit. The Info pages were created using text and graphics pulled directly from the posters and put into a digitized form. The two pages of importance is the Estuary page, which is based on the *Rhythms of Our Coastal Waters* poster, and the LOBO page, which is an interactive series of pages that features the different instruments included in the LOBO package.

Iterations and Changes made to the exhibit

Posters

Many of the revisions made on the posters were based on reducing the amount of text, increasing the number of pictures, graphics or figures, or changing background colors. Posters were developed as one of the first entry points into the exhibit. In the first versions were text heavy with limited visual objects that are appealing to the eye. The goal of the researcher during development was to get as much background

information across as possible and answer any type of question a visitor might have about the topic on the poster. Since accomplishing this is not feasible in a way that is appealing to visitors, the many subsequent revisions for each poster focused the text around the core messages and streamlined the overall visual aesthetic. There were several versions for each poster, so the changes made between the initial and final versions will be discussed here.

Rhythms of Our Coastal Waters

The structure and methods of communication in this poster were maintained through all the revisions. As mentioned, text reduction for ease of understanding and increasing visual appeal were the majority of the changes for this poster (Fig 7). The diagrams and cartoons used to support understanding of the concepts presented in the text, including the addition of an ocean/estuary/river cartoon and removing extraneous figures like sheet music and a heartbeat, were also simplified.

Salinity Seasons

Being one of the most revised posters, only two of the original sections from the initial version were maintained in the final version. Overall, visitors were not interested in the just text and graphs in the first version, so most of the text was removed and replaced with cartoons of the differences between summer and winter above and below the estuary (Fig 8). The overall goal of the poster was to impart on the visitors the two different types of water that change the salinity in the estuary and understand the differences between the two seasons, so the extraneous text explaining why understanding seasonal patterns is important and how seasonal salinity patterns are defined in the estuary, was removed. The inclusion of the cartoons also added color, increasing the visual appeal of the poster as well.

LOBO

Out of the four posters, this poster underwent the most dramatic revisions. The initial poster featured mostly text with two small pictures of what the instrumentation looks like and where it is deployed (Fig 9). All of the changes to this poster between the initial and final version took place before any visitors saw it; the technical team of the working group suggested the new design to highlight the different instruments and components that make up the LOBO. The final poster features pictures of all the different instruments with small amounts of text that describe what variables each measure.

Why are we collecting this data?

Like with the Rhythms of Our Coastal Waters poster, only minor changes to the text and overall appearance were made (Fig 10). The feedback from visitors and COAS students and researchers initiated the change of the textbox shapes to make them less distracting. The changes in the photos included in the food chain were to use photos from Oregon Sea Grant instead of non-approved photos collected from various sources online.

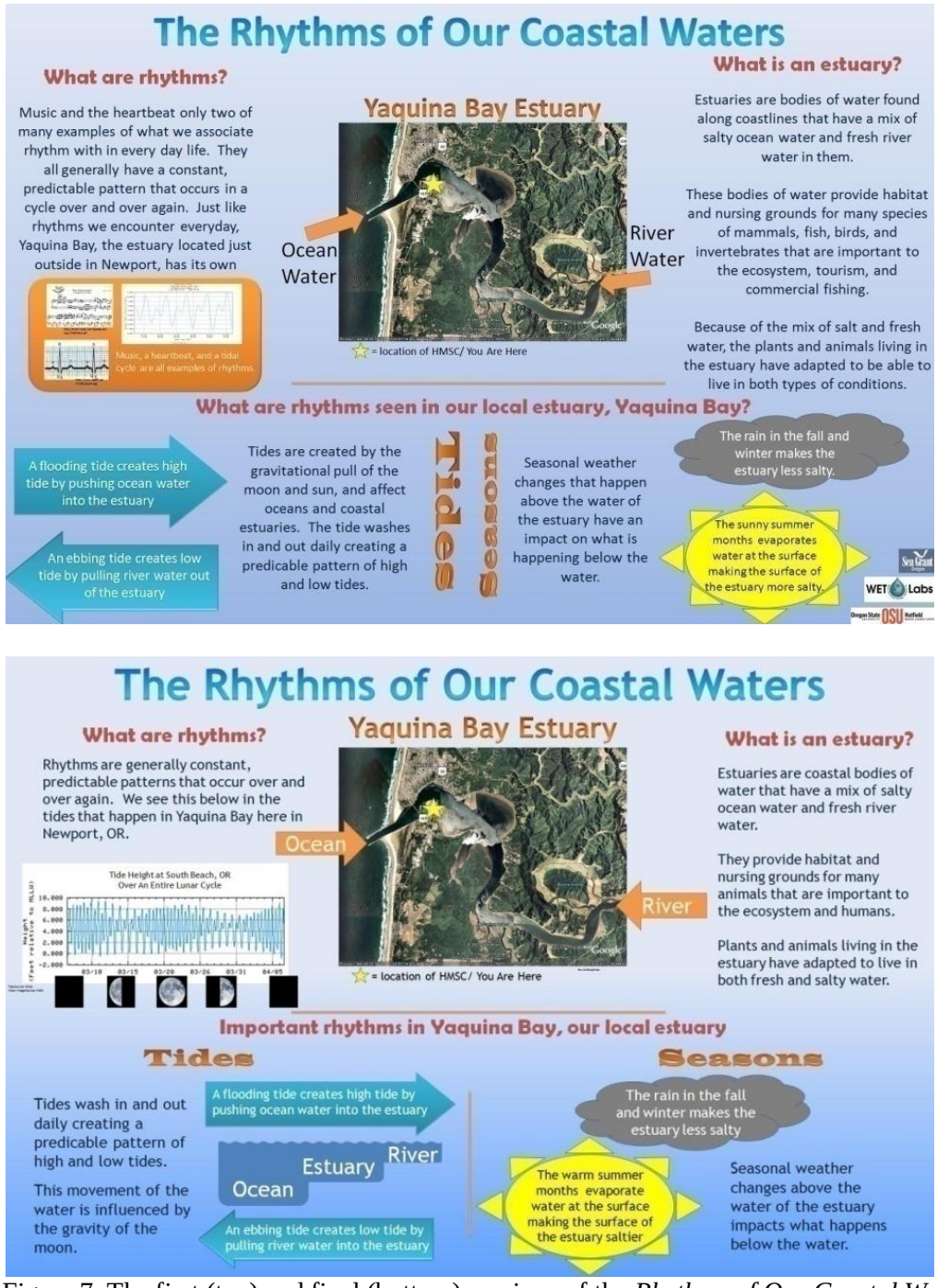


Figure 7. The first (top) and final (bottom) versions of the *Rhythms of Our Coastal Waters* poster.

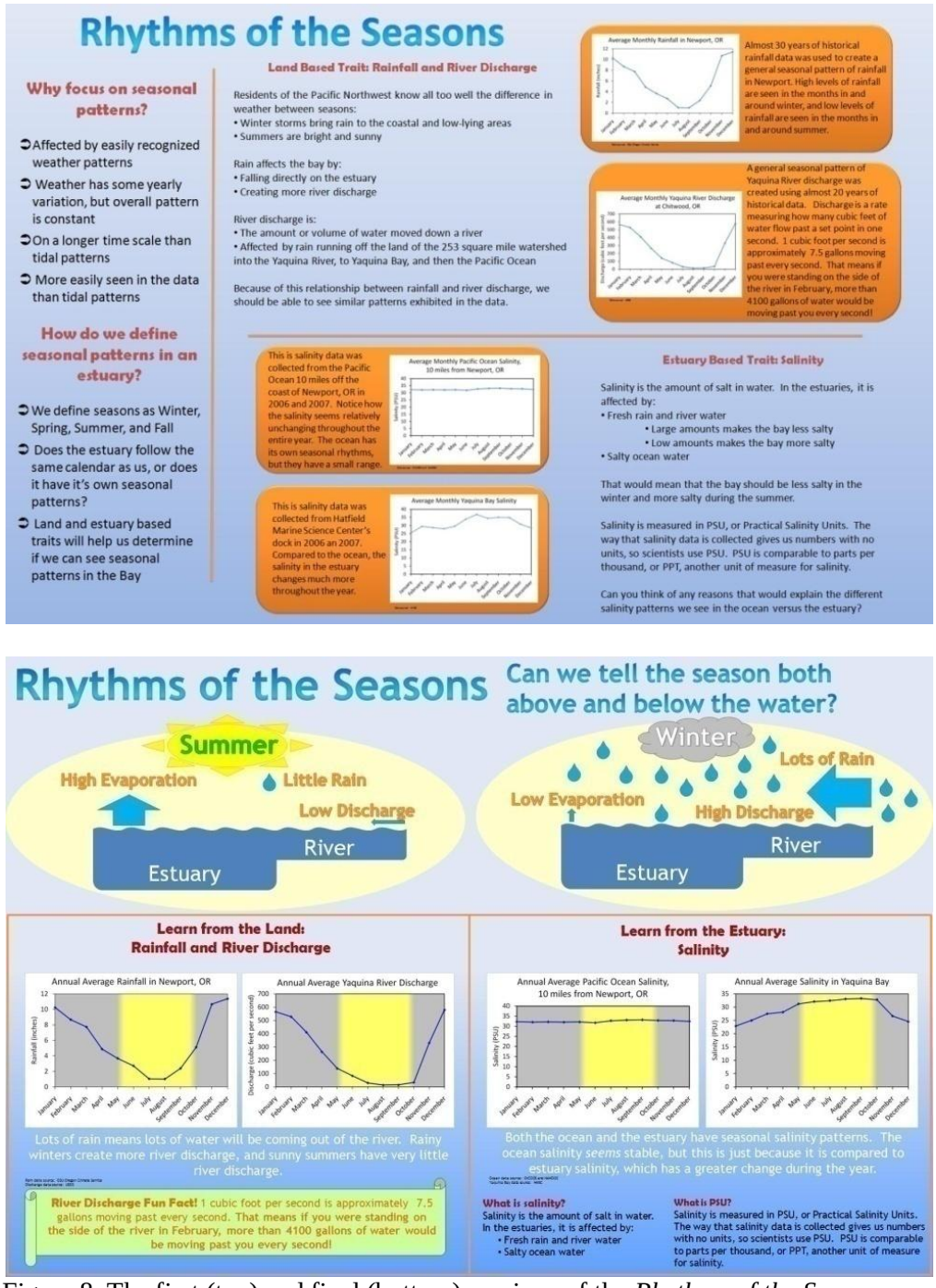


Figure 8. The first (top) and final (bottom) versions of the *Rhythms of the Seasons* poster.

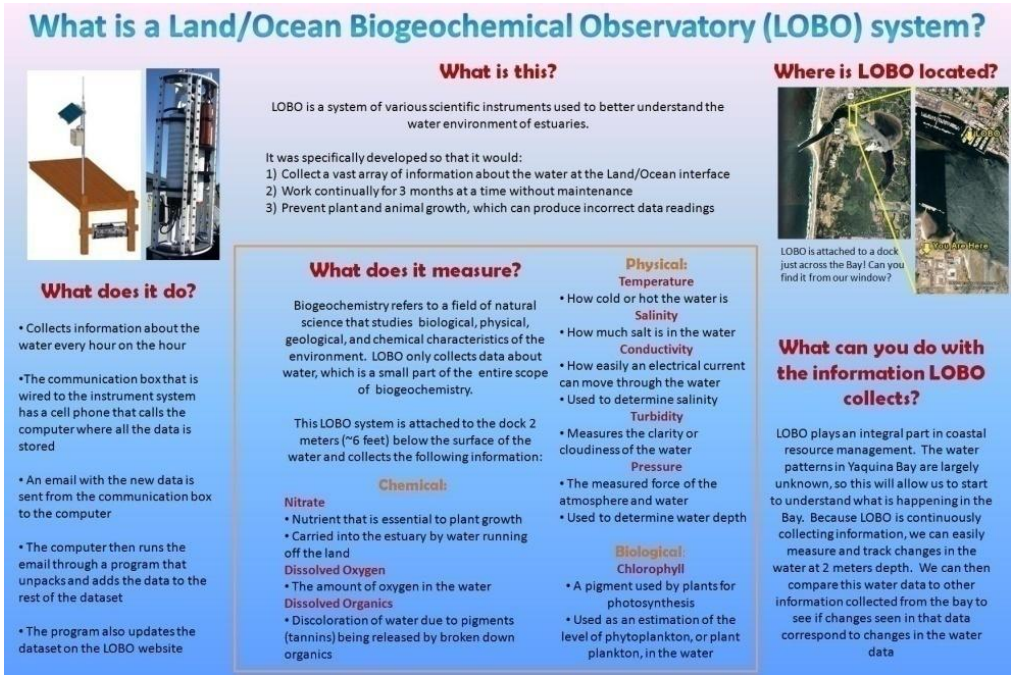
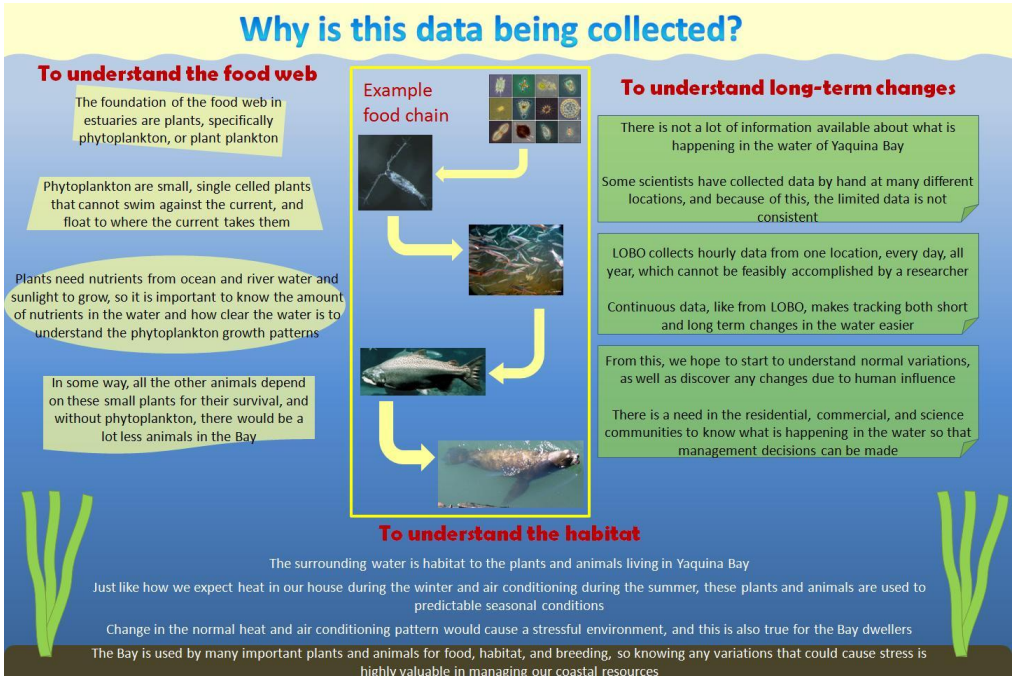


Figure 9. The first (top) and final (bottom) versions of the *LOBO* poster.


Why is this data being collected?
To understand the food web
The foundation of the food web in estuaries are plants, specifically phytoplankton, or plant plankton
Phytoplankton are small, single celled plants that cannot swim against the current, and float to where the current takes them
Plants need nutrients from ocean and river water and sunlight to grow, so it is important to know the amount of nutrients in the water and how clear the water is to understand the phytoplankton growth patterns
In some way, all the other animals depend on these small plants for their survival, and without phytoplankton, there would be a lot less animals in the Bay
Example food chain
To understand long-term changes
There is not a lot of information available about what is happening in the water of Yaquina Bay
Some scientists have collected data by hand at many different locations, and because of this, the limited data is not consistent
LOBO collects hourly data from one location, every day, all year, which cannot be feasibly accomplished by a researcher
Continuous data, like from LOBO, makes tracking both short and long term changes in the water easier
From this, we hope to start to understand normal variations, as well as discover any changes due to human influence
There is a need in the residential, commercial, and science communities to know what is happening in the water so that management decisions can be made
To understand the habitat
The surrounding water is habitat to the plants and animals living in Yaquina Bay
Just like how we expect heat in our house during the winter and air conditioning during the summer, these plants and animals are used to predictable seasonal conditions
Change in the normal heat and air conditioning pattern would cause a stressful environment, and this is also true for the Bay dwellers
The Bay is used by many important plants and animals for food, habitat, and breeding, so knowing any variations that could cause stress is highly valuable in managing our coastal resources

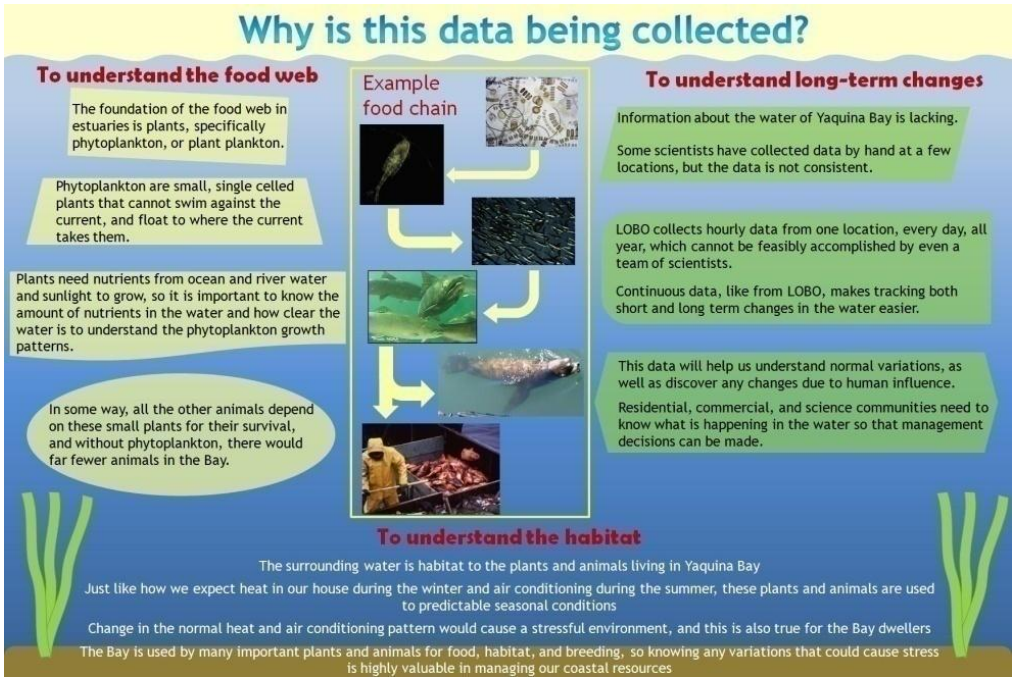


Figure 10. The first (top) and final (bottom) versions of the *Why is this data being collected?* poster.

Computer Main Features

The interactive computer component evolved over the period of evaluation and the following text outlines the design elements for each of the three computer exhibit versions. Table 1 provides a quick reference to show the differences between the three versions and should be utilized during the following three sections for ease of understanding. Table 2 outlines the changes in button text between the three versions, where the Introduction buttons are located on the second Intro page, and the Navigation buttons are located on every page as part of the side navigation bar, and should be utilized to ease comparison of the different versions as well.

Table 1. The changes in the exhibit attributes between the three computer versions.

	Version 1	Version 2	Version 3
Introduction			
One slide	●		
Three slides		●	●
Content			
Animation for scaffolding graphs	●	●	●
Animation for scaffolding concepts			●
Animation for entrances		●	●
Mascot pictures		●	●
Information in textboxes	●		
Information in speech bubbles		●	●
One type of textbox	●		
Multiple types of textboxes		●	●
Acknowledged only incorrect answers	●		
Acknowledged correct and correct answers		●	●
All graphs static	●		
L1 graph animated, all rest static		●	●
Navigation help	●	●	
Help slides with information from posters		●	●
Navigation			
Home button	●	●	●
Back arrow button	●	●	●
Forward arrow button	●		
Forward arrow button with text		●	
Continue button			●
No forward arrow on multiple choice slide	●	●	●
Navigation buttons grey	●	●	●
Current level navigation button blue		●	●
L1: touch above line		●	
L1: touch in box			●
Navigation Help button	●		
Help button		●	
More Info button			●

Table 2. The button titles for the three exhibit versions.

	Version 1.0	Version 2.0 (Fall 2008)	Version 3.0 (Winter 2009)
Introduction buttons			
L1	Level 1: How do we build graphs from data?	Plankton level: How do we build graphs from data?	Level 1: Check out how graphs are built using salinity data
L2	Level 2: Interpreting historical graphs	Mussel level: Explore the links between rainfall, riverflow, and salinity	Level 2: Explore the links between rainfall, river flow, and salinity
L3	Level 3: How to read graphs of LOBO data	Crab level: How to read real-time data salinity graphs	Level 3: Learn how to interpret real-time salinity graphs
L4	Level 4: Investigating rhythms using LOBO data	Rockfish level: Investigating rhythms using real-time data	Level 4: Challenge your abilities with a rainfall and salinity match-up
L5	Level 5: Test your LOBO data abilities!	Sea lion level: Discover Yaquina Bay's story	Level 5: Test your data sleuthing skills to explore Yaquina Bay's story
Navigation buttons			
L1	Build a graph (Easy)	Build a graph (Plankton)	Build a graph (Level 1)
L2	Interpret Graphs (Moderate)	Interpret Graphs (Mussel)	Interpret Graphs (Level 2)
L3	Read LOBO Graphs (Challenging)	Read LOBO Graphs (Crab)	Read LOBO Graphs (Level 3)
L4	Investigate LOBO Data (Difficult)	Investigate LOBO Data (Rockfish)	LOBO Data Match-up (Level 4)
L5	Test Your LOBO Abilities (Expert)	Test Your LOBO Abilities (Sea lion)	Test Your LOBO Abilities (Level 5)

Version 1

Introduction/exhibit entrance

The first slide of the exhibit was the only introduction to the exhibit and its content. It featured the title of the exhibit and one button to each of the five levels. The titles of the level buttons are seen in Table 2, and were either arranged in one column next to an arrow indicating the range from the easiest level to the most difficult, or in two columns, one with the title "Unsure of how to read graphs?" over the Level 1 and 2 button column, and "Want to jump right in to playing with LOBO graphs?" over the Level 3, 4, and 5 button column. No additional information was included to introduce the exhibit and its content to the visitors, besides the four posters

that surrounded the computer. It was assumed that the posters would act as an introduction and that the visitors would refer to them before or during the computer use.

Content

The content was presented in a very scientific, logical manner. Except any introductory or transitional slides, all the slides featured static graphs and text boxes. For the majority of the slides, no entrance animation was used so the content on each slide appeared at the immediately as the slide was changed. The only animations used in this version was to highlight how to plot data points in Level 1, and to scaffold interpretation of graphs in Levels 2 and 3. Only incorrect answers were acknowledged.

Navigation

As noted before, navigation between slides was achieved using hyperlinked action buttons. Every slide, except the first home slide, featured a home and back arrow button in the lower right hand corner. Every slide with a home and back button either had a forward button, if no multiple choice action buttons were present, or multiple choice action buttons to navigate forward in the exhibit. On multiple choice slides, the forward arrow button was removed and the space was left blank. The multiple choice buttons were consistently red, and the side navigation buttons were consistently grey. The side navigation buttons were labeled with the level name and difficulty ranging from easiest (Level 1) to expert (Level 5) (Table 2). Because of the inherent programming in the kiosk mode of PowerPoint, after five minutes of inactivity the exhibit automatically went back to the start page.

Interface

The interface for this first version was also very sterile (Fig 11). All the buttons, text boxes, title bars and side bars are sharp-cornered rectangles. To maintain consistency of look, all the action and navigation buttons were formatted with the same beveling effect. All of the text boxes, regardless of the type of text or function of that text box, was a golden yellow color. The majority of the slides only had one or two text boxes.

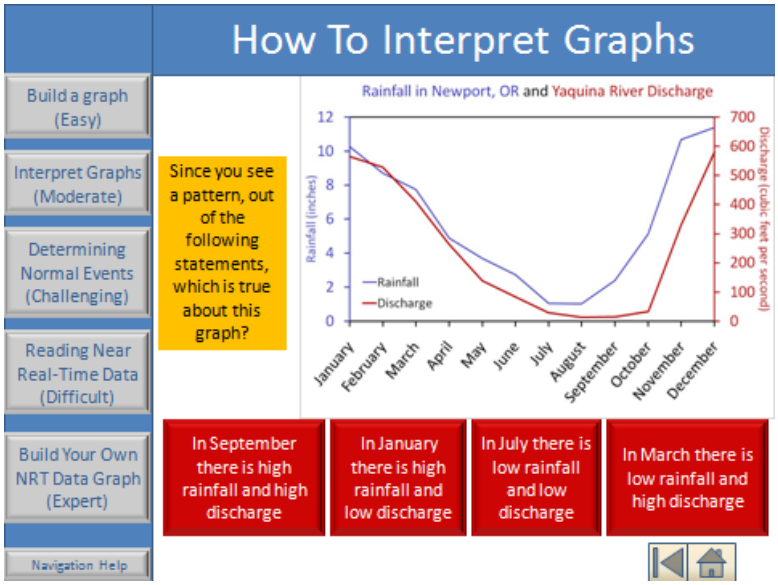


Figure 11. Example slide from L2 in V1.0.

What worked

The feedback used to shape the revisions to this version was primarily from groups targeted outside of the VC. The working group were intimately involved with every stage of the design and development process that their comments are not included here since they helped during the creation process to build a model that fit the initial design vision. At the VC, non-targeted/solicited visitors showed interest in the exhibit's information by stopping and looking at/reading the posters around the computer. A targeted audience, the COSIA class, went through Level 2 together, and

they enjoyed answering the questions and interacting with the multiple choice buttons. They also commented that the side navigation buttons were helpful and the text was clear to understand.

What didn't work

Even though the visitors showed interest in the posters and the class showed some level of enjoyment, there were many elements that didn't meet their expectations.

Issue: Lack of computer use

At the VC, many adult visitors would look at the computer while stopped at the posters or on their way past the exhibit and not interact with the computer at all. The working group thought that a possibility to explain this is because it was a computer and a mouse and many people use those technologies for work, and didn't want to be on a computer during their leisure time. Another possibility is that there was nothing on the computer screen that enticed the visitor to interaction with the computer. Even though adults were not interested in interacting with it, several children would run from across the VC over to the computer and start clicking around. They would leave soon after.

Other unsolicited comments helped shape the changes made to make Version 2. One of the staff members of COAS went through the exhibit by himself when it was up at the VC, and reported back to the researcher that he didn't understand what was expected of him as he went through since there was no introduction or directions. Two MRM graduate students, who went through the exhibit while the researcher was watching their interaction, suggested using a mascot that connects with the visitor instead of just having graph and text on each slide. Finally, a fellow conference attendee at Ocean Sciences 2008 suggested the format for Level 1 in Version 2 to help

engage visitors right away. All of these comments were attended to and reflected in changes made to create Version 2.

Issue: "Did we get it right?"

The COSIA class, who actually interacted with one of the levels, also had some feedback to improve on. In Level 2, only incorrect answers were acknowledged; the design was that if they got an answer correct they would just move on to the next question, which assumes that the visitor would understand that they got the answer correct since they moved on to the next question. The class, every time they got an answer correct, one or several students would ask out loud "Did we get it right?".

Version 2

Introduction/exhibit entrance

Issue addressed: Lack of computer use: attraction

The introduction to the exhibit changed from one slide in V1.0 to three slides in V2.0. The first slide is what is referred to the Home slide, features a birds-eye-view picture of Yaquina Bay, the title of the exhibit, "Rhythms of Our Coastal Waters: Yaquina Bay", and a large red button with the text "Touch here to continue". The next two slides featured the five different mascots, one for each level, introducing various types of information about the exhibit, including information and buttons for more information about the estuary and LOBO on the first page, and explaining the exhibit and the levels on the second page. The second page also featured the buttons to the different levels in the same two column format as V1.0. Table 2 shows the slight changes made to the text on the level buttons.

Content

Issue addressed: Lack of computer use: becoming more personable

As previously mentioned, the display and presentation of the content, and not the content that was there already, was a necessary area of improvement. Five mascots were added, one for each level. Because of the programming limitations, these mascots were static photos of five different animals that live in Yaquina Bay's food web: a juvenile crab plankton for Level 1, a blue mussel for Level 2, a Dungeness crab for Level 3, a rockfish for Level 4, and a sea lion for Level 5. These mascots were also named based on their common or scientific name, though the names were only mentioned when the mascot introduced itself on the first introductory slide of each level: Mega the crab plankton; Myt the mussel; Dungie the crab; Seb the rockfish; and Stella the sea lion. The mascots were also arranged in order of the base of the food web at Level 1 and the apex of the food web at Level 5. Instead of using just text boxes to relay all text, the mascots afforded a different text box shape, a speech bubble, which makes the presentation of the text more personable (Fig 12). This also afforded less formal language since the mascots are "speaking" to the user, and made the presentation of some information and questions less convoluted. An entrance animation was applied to the mascots so that they entered from the left after changing slides.

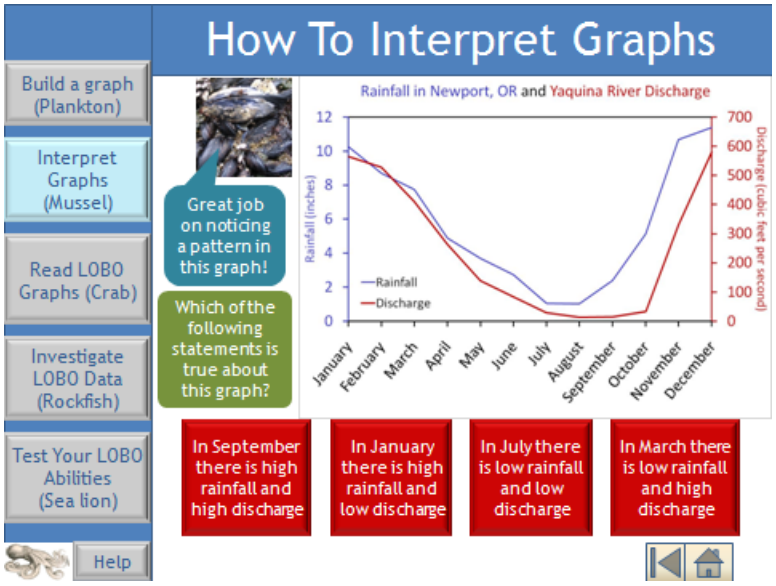


Figure 12. An example slide from L2 in V2.0.

Issue addressed: Lack of computer use: entertainment and aesthetics

As in V1.0, the majority of V2.0 graphs remained static. Graphs in Level 1 changed, though, and now includes no static graphs. This level begins with a horizontal salinity scale, from 0-40 PSU, and questions prompt the visitor to touch above the salinity line where they think the average Pacific Ocean, year-round Yaquina Bay, winter Yaquina Bay and summer Yaquina Bay salinity would fall along the line. After each of these four prompts, the visitor received either a "Great job" or "Not quite" along with some text explaining where the average salinity is. After this exercise, there are several prompts that the visitor initiates that rotates the salinity line to become vertical, add a horizontal axis with tick marks and labels of each month, and then adds bars and then data points with a connecting line based on the average salinity data from LOBO. Entrance and motion animations are used heavily in this level to scaffold learning and build the graphs in the second part. Besides Level 1, all of the same graphs used in Levels 2 and 3 in V1.0 remained in place for V2.0. Some

graph transitions or entrances were animated to highlight a change from one graph to another, but most were present as the slide was changed.

The text boxes from V1.0 were altered based on the type of text presented. In V2.0, there are three different types of text boxes (Fig 12): information or facts presented by the mascot in a blue speech bubble; directions for navigation or a question to be answered in a moss green, rounded cornered rectangle; and a correct or incorrect answer indicator in Levels 1 and 2 in a bright green, oval speech bubble. The text boxes were animated to have a staggered entrance so that not all the text was on the slide initially. The larger speech bubbles entered in the same manner as the mascot pictures; the two types of green text boxes enter by dissolving into place. Some of the red navigation buttons are present as the slide changes, but on some slides they enter by rising up from the bottom of the page after all the other text boxes have entered, indicating to the visitor that all the information for that slide have been presented.

As noted in Table 1, an expanded help section was also developed that included the Info pages as more background information for visitors.

Navigation

Only a few changes were made to the navigation system in V2.0. All the home and back arrow buttons were maintained, as well as any forward arrow or red navigation buttons on multiple choice questions. On slides that had only a forward arrow button, a moss green text box was added near the arrow button with the text "Touch the forward arrow button to continue". On the side navigation buttons, the grey color was also maintained except for the level that the user was already in, which was a blue color instead. Because of the inherent programming in the kiosk mode of PowerPoint, after five minutes of inactivity the exhibit automatically went back to the home page.

Interface

Except for the text box changes mentioned in the content section, no interface elements were changed.

What worked

The overall themes from the interviews of the visitors that used the exhibit for four or more minutes was that the text and information was easy to understand but challenging enough to keep their interest, they enjoyed using the touch screen, and they are interested in the scientific content related to the estuary, LOBO, and the dataset.

Some of the main issues or problematic areas identified in V1.0 included the initial attractiveness and then subsequent holding power of the exhibit so that visitors actually use it. The previous comments support the idea that V2.0 mitigated these problem areas, partial due to the addition of the touch screen and the change to the three introduction slides. Even though there was no information on the home page about the exhibit, visitors still touched the big red button to find out. The next two introductory slides allowed visitors to get a sense of what the exhibit was about, and the 5-button intro page gave visitors a choice to continue their interaction in the level of their choosing, or to leave, which some did. Overall, the red button on the home page, the addition of the mascots and animations, and the modification of L1 and the text boxes increased the number of visitors that used the exhibit. Visitors of all ages used and enjoyed L1; one 6 year old girl sat alone and read out loud to herself, answering the salinity questions in an appropriate manner. Many multi-generational groups also seemed to enjoy using the first two levels, where the adults explained or worked through the level with the children or adolescents in the group. Another simple fix was identifying if the user answered correctly or not, which is an important design aspect to support flow experiences (Rowe & Wertsch, 2002), after an input.

Since the incorrect answers were already identified, markers were then put in for correct answers as well, and the response from several groups observed was cheering when they got an answer correct.

From the interviews, visitors reported learning information regarding bay and ocean salinity, the importance of rainfall and the affect it has on the Bay's salinity, and the definitions of some of the more "jargon-y" words, like estuary and PSU. Information and discussion related to what visitors reported as having learned at the exhibit will be presented in detail in Learning Claim 1 in Chapter 5.

What didn't work

Overall, the main themes brought up by visitors in response to the question regarding challenges faced in the exhibit where that some of the design elements are confusing or overwhelming, some of the instructions and information was not explicitly explained or easily navigated to, and that some of the information and methods of interacting with the exhibit where not appropriate for children. From the interview feedback and observed behaviors, several elements in V2.0 in need of modifications were identified and are outlined below.

Issue: Ease of navigation

In Level 1, visitors were asked to touch above the line, which had a large blank space above it. The boxes for the visitors to touch in were invisible, but tall enough to encompass a large area for them to touch in. The researcher observed many visitors having difficulty interacting with the line, either touching on or below the line, which may have been due to the fact that the visitor didn't read or see the directions, since they were not near where they had to touch, or they read them and didn't understand where in the blank space they were supposed to touch. Also, the text boxes on the slides with a forward arrow button confused some visitors as well, mostly the senior

citizens. Most visitors were able to follow the instructions and touch the next button arrow, but one visitor kept trying to touch the actual text box with the instructions to move on, which the researcher believes is an artifact of being a internet/computer novice.

Issue: Animation function was inconsistent

Even though all the animations were thoroughly planned and implemented, the programming of PowerPoint did not allow all the visitors to see the animations. It is built into PowerPoint that once a slide has run through, or built, all of its animations, it is then done with the building process for that slide, and as long as the presentation stays in SlideShow view mode, whenever that slide is viewed again, it will be viewed as the completely built version, so no animations will run. This means that the first visitor to look at a slide will see the animations, but all the visitors that view the slide after that will only see all of the text on the page all at once, which is why some of the visitors thought the pages were overwhelmed with text.

Issue: Visitors didn't show interest in the "harder" levels

Another observation was that many visitors navigated to the "harder" levels, but then either quickly went through them, quickly navigated away from them, or quickly left the exhibit. These levels are inherently less scaffolded, and in this design, therefore have less direct interaction from the visitor. Even though questions were posed throughout L3 to make the visitor think about what they saw in the graphs, this was not an element that made them slow down to think about it. Also, the directions of how to use the web interface, as accessed through L4 and L5, were at the end of L3, which again, the visitors that made it that far, just breezed through. This was not seen in the previous evaluation round since no visitors had made it that far, so the assumption that visitors will first go through L3 and then on to L4 or L5 to implement

those instructions are not valid. Also, visitors were unsure of what the directions in L4 and L5 are asking of them, so these will also have to be re-evaluated.

Issue: What is PSU?

Lastly, a question asked by many visitors, as well as many of the volunteer docents at the VC is "What is PSU?". It was decided that Practical Salinity Units, or PSU, would be used as the units for salinity since that is more scientifically correct that using parts per thousand, or ppt. The definition of PSU was on the salinity poster as well as the salinity more information slide, which could be accessed anytime by touching the Help button which went to the Help slide with buttons hyperlinked to the Navigation help page as well as all of the different information pages. It was assumed that the visitors would navigate or use these resources when they had a question such as this, but that apparently was not happening.

Version 3

Introduction/exhibit entrance

The home page with the two introduction slides were maintained as is, except for some slight changes in text. On the first information page, the text introducing LOBO changed from "Researchers are currently collecting data about the water in the Bay" in V2.0 to "Researchers are … in the Bay using an instrument named LOBO" in V3.0. The text on the button next to this text that is linked to the LOBO page was also changed from "How are these data being collected?" in V2.0 to "What is LOBO?" in V3.0. The text on the five buttons on the second page were changed as well (Table 2).

Content

Issue addressed: Animations didn't work sometimes

The researcher found three methods to work around the PowerPoint build issue. One needed programming understanding, which was not a feasible avenue, one doubled the amount of slides, and with 87 slides in V2.0 and 142 in V3.0, this was not a feasible avenue either, and the last was to convert the PowerPoint into a flash file. The flash file would allow the animations to run every time that slide was navigated to; however, it lost the ability to go back to the home page after five minutes of inactivity. To get around this, a small sign was placed on the side of the monitor asking the visitors to touch the home button when they were done using the exhibit. After the first day of observations of V3.0, home buttons were then added to the two introduction slides as well.

Issue addressed: Visitors didn't show interest in the harder levels

The content and delivery of Levels 1 and 2 seemed to work with the visitors, so the Hard levels, Levels 3, 4, and 5 were changed in hopes of promoting more interaction and conversation at the exhibit in hopes of creating more meaningful interactions with the content. Level 3 previously was not as step-wise as intended in its layout and delivery of content, so it was modified to flow more logically from one graph to the next. In V2.0, the graph sequenced from a full year, monthly averaged graph to a daily averaged graph of 20 days for summer and winter, then down to hourly data graphs of 10 days in the summer and the winter, and then zooming back out to hourly data graphs for 3 months for each season. The questions posed focused on what could be making the changes seen in the daily averaged and hourly data graphs for each season, which is the amount of rainfall and tides. The researcher realized that the theme and message for this level was not explicit and made many modifications.

In L3, there are three sections, one introducing how to interpret hourly data graphs, one about how tides change the Bay's salinity, and a final challenge section to test the visitor's understanding. In the first section, all of the graphs are for an entire

year, and the sequence starts with the monthly averaged graph in L1 and L2, then breaks up into the monthly averaged graphs for each year that made that graph, 2006, 2007, and 2008. Along the way, more specific/targeted questions were asked than what were in V2.0, and asked the visitor to categorize the type of graph shown as a seasonal, monthly, daily, tidal or hourly variations and patterns. The second section featured a series of animated cartoons that scaffold how salinity changes as the tides ebb and flow in the estuary. The last section features four challenge questions; the first two ask the visitor to count how many high and low tides there are on first a graph of tide height over five days and then count the tides again on the hourly data salinity graph for that same time period. The first series of graphs featured an "easy" salinity pattern and the second featured a harder salinity pattern where it was difficult to know exactly where the tides where. The third challenge question was to determine which season two hourly salinity graphs over a nine week period belonged; the y-axis range was different for each graph to make the resulting salinity lines look similar. The last challenge question asked the visitor to count how many storm periods there were from November to January of 2006 and 2008; those two years were selected because they exhibited such different patterns.

In V2.0, Level 4 was very similar to Level 5, and since not too many visitors were interested in interacting with either level, the content for these were changed. In V3.0, L4 became a more explicit challenge that allowed the visitor to engage with the RTD graphs without interacting with the web interface to build their own graphs. The assumption was that the interface acted like a barrier to viewing the RTD graphs, so the new design of this level cut that out. Also, it was assumed that visitors would react positively to a challenge activity. L4 became a challenge to match up four daily rainfall graphs of 20-day periods with the salinity graphs of those same periods. The rainfall graphs did not have date labels, and there were four red buttons with date ranges that are hyperlinked to a URL that brought up the salinity graph of that time period from the LOBO website. The slide also included another red button that allowed the visitor to check their answers when they were done matching the rain and

salinity graphs up. The next slide had four graphs with the rain and salinity graphed together.

Finally, L5 was changed to incorporate parts of L4 from V2.0. In V2.0, L4 asked the visitor to use the LOBO website, graph either the past 24 hours, week, two weeks, or month, and try to interpret what caused the salinity change they observe during that time period. A prompt for if they got stuck to graph the salinity from November 25, 2007 to December 11, 2007 and explain what happened was also included. L5 in V2.0 also asked the visitor to use LOBO's graphing interface to find a 24 hour period that had a salinity change of at least 10, 15, or 20 PSU, a week period where the salinity didn't change more than 2 PSU, or any other period of time that was interesting to them. L5 of V3.0 condensed these two into two columns of tasks, one being "Find the salinity…" with the questions "What is the salinity for the past 24 hours, week, or month?" and "What is the lowest salinity of the most recent rain storm?", and the other column being "Find when…" with the questions "Is there a week when the salinity didn't change more than 2 PSU?" and "Is there 24 hours when the salinity changed at least 10, 15, or 20 PSU?". The instructions for using the web interface were also moved to L5, with a separate button on the slide labeled "Not sure how to begin? Touch here to see an example".

Issue addressed: What is PSU?

The explanation of what PSU is was moved from the Salinity information page to its own page. The page consisted of the text taken from the salinity slide, as well as 1,000 3D circles with an animation showing the visitors what is meant by 5, 10, 15, 25, and 35 PSU, which is equivalent to ppt. Buttons to access this page were placed on the first slide of every level that used the term PSU, as well as on the More Info page that can be accessed from any page. This ameliorates the assumption that visitors would use a help button if they don't understand something.

Navigation

Issue addressed: ease of navigation

Navigation was made more explicit and consistent in V3.0. All the forward arrow buttons and text boxes with navigation instructions were removed and replaced with a red button with the text "Touch here to continue". All of these red buttons were the same size and placed in the same position on the slide, either on top of or to the left of the home and back buttons. The home and back buttons were maintained on all the pages that had them previously, and they were moved to the right to fill in the gap left by the forward button.

There were a few minor specific areas of navigation that were improved within the levels as well. With the animation fix, whenever a visitor navigated to the estuary or LOBO pages from the first introduction slide, and then back to introduction slide, they had to go through all of the animations again before the navigation button popped up. After the first day of observations, the button animation was removed so that it was present at all times to lower visitor frustration. The titles on the five navigation buttons on the second introduction page were also altered, especially to not mislead visitors into assuming L5 was something that it was not (Table 2). To address the problems people had with the salinity line in L1, a box was outlined below the line with a text box directly under the box with directions to touch in the box below the line. In L5, the hyperlinked object to access the web was a screenshot image of the LOBO website, which was confusing to some visitors. This was removed, and a red button when the text "Touch here to visit the LOBO website and see the data online!" replaced it.

Interface

The look of V3.0's interface was updated from a square, 2D, Windows95 look to a rounded, 3D Windows XP look (Fig 13). The title and side bar became 3D, the

side bar rounded, and the side navigation buttons became rounded-cornered instead of sharp-cornered. This change was not as much precipitated by visitor comments, but because the researcher wanted some change.

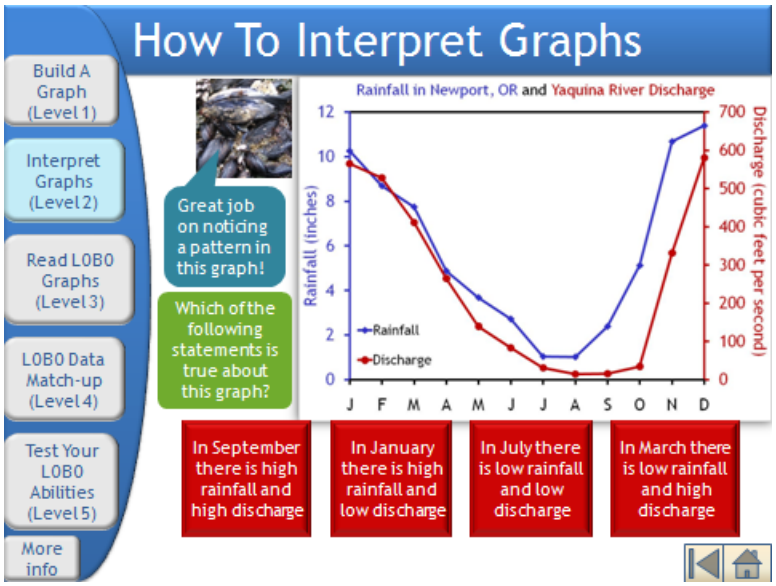


Figure 13. An example slide from L2 in V3.0.

What worked

The overall themes from the interviews of the visitors that used the exhibit for four or more minutes for this version were similar in content to the comments made about V2.0. Visitors found the content and instructions were straight forward and step-wise, enjoyed the animations, and appreciated how the levels became more advanced and increased in difficulty as you moved up the levels.

From the interviews, visitors in this evaluation round again reported learning similar information as those in the previous evaluation round. Comments included information regarding bay and ocean salinity, the importance and occurrence of rainfall in the Pacific Northwest and the affect it has on the Bay's salinity, and youth learning how to read and interpret graphs. Information and discussion related to what

visitors reported as having learned at the exhibit will be presented in detail in Learning Claim 1 in Chapter 5.

The three issues previously identified and addressed by exhibit modifications that resulted in positive feedback was related to the animations, content of hard levels, and navigation. Converting the PowerPoint file to a flash file worked very well; we did lose the capability of going back to the Home page after 5 minutes of inactivity so the addition of the home button to the two Intro slides was especially helpful. Qualitative observations noticed that some visitors enjoyed the changed content in the Hard levels and it seemed these were a little less ignored than the Hard levels in V2.0. Finally, the navigation hurdles were successfully addressed by using one navigation button with the "Touch here to continue" text consistently on every page and the addition of the box in L1 instead of having just an open white space.

What didn't work

Most visitors interviewed did not have any specific comments related to elements in the exhibit that were challenging to use or understand and responded with an answer of "nothing". However, a few visitors made contradicting statements that they thought the exhibit was either designed for children or too difficult for children to understand. The following issues listed are based on the observations of visitor use.

Issue: Navigation

Even though the navigation within L1 was observed to have improved from V2.0 to V3.0, some visitors were still showing signs of struggling with touching inside of the box. The reason the box was placed above the line and not layered on top was because hyperlinks do not work with a 100% transparent object since there is not solid object to attach the hyperlink to. It was realized later that making an object 99% transparent maintains the same relative transparency as 100% transparency but has a

solid object that a hyperlink can be attached to. If modified in the future, L1 of the exhibit will feature this type of hyperlinked object that will be layers on top of the salinity line. Also, it was noted that not all visitors navigated back to the home page after completing their interaction with the exhibit.

Issue: Animations

Where the animations are an affordance in some areas of the exhibit, the constant recurrence of the animations at the start of each slide did seem to be a constraint as well. It was noticed that visitors who went to either the Estuary or LOBO page from the first Intro page were visibly frustrated at the wait for all the animations on that page to complete when they navigated back after visiting the Info page since the navigation button popped up at the end of the animation sequence. Because of this the navigation button on the first Intro page was always present for those visitors who had already seen the page could move on without waiting for the animation to conclude, but this allowed other first time visitors to skip past that slide without reading it. The affordance of having the navigation pop up at the end was to slow some visitors down to engage with the text, but this did not afford quick navigation for visitors who had already viewed the page.

Issue: Content

The changes to the Hard levels were possibly in the right direction, but still need some tweaking. After observing use of L3 it appears that the level itself is now too long due to attempts to be more thorough and step-wise; one group was observed ending their interaction in the middle of the level, but one group did stick it out the whole time. The group that did use L3 to the end also attempted L4, but curiously didn't use the web-based salinity graphs and just used the dates on the buttons to complete the challenge. Finally, it was observed that visitors still didn't understand

what PSU was, with one group referring to it as PSI, pounds per square inch, so a change in tactic when referring to salinity units is recommended for future versions of the exhibit.

CHAPTER 4: DESIGN-BASED FINDINGS

Introduction to Chapters 4 and 5

Chapters 4 and 5 are a different type of approach to presenting the results and discussion of this study. In order to succinctly and logically present the findings of the project, instead of separating results and the discussion, they are presented together to support a series of claims that can be made about our findings. The claims are separated into two chapters, with Chapter 4 presenting claims about the design of the exhibit, and Chapter 5 presenting claims centered around learning that occurred at the exhibit.

Standard exhibit use by the visitors

Many use characteristics of the exhibit that are referred to throughout this chapter will be compared to the standard use patterns seen when all visitors are combined. These standard patterns of first visits, total visits, the amount of time spent at the exhibit, and talk will be presented here and are meant to be used as a reference when discussed in further claims.

Visitor group composition

In all, 146 visitor groups were observed using the exhibit during the fall and winter with 73 groups observed in each evaluation round. Visitor demographics were coded in two ways, group size and group type. Information about the group demographics were constantly recorded during the entire observation process, so people who joined the group after the initial interaction with the exhibit were included as part of that group. People who left the group in the middle of that group's

interaction were still maintained as part of that group. Groups were coded by number of people in them (individuals, pairs of two, or groups of three or more) based on the number of people that were part of that group in total during the entire interaction with the exhibit. Groups were also coded for group structure (individual youth, individual adult, peers, or multi-generational), with individual children and teens who appeared to be under 18 coded as individual youth.

Table 3. Chi-square analysis of group types in the fall and winter evaluations.

	Individual Youth	Individual Adult	Peers	Multi-generational	X^2	p-value
Fall 2008	51.5%	66.7%	48.3%	39.2%	6.104	0.107
Winter 2009	48.5%	33.3%	51.7%	60.8%		

Table 4. Chi-square analysis of group sizes in the fall and winter evaluations.

	Individual	Pair	3 or more group	X^2	value
Fall 2008	59.1%	41.4%	45.5%	4.088	0.130
Winter 2009	40.9%	58.6%	54.5%		

The groups observed during each evaluation round were a sub-sample of all the visitors at the VC, and the assumption is that each evaluation round should have a similar composition of groups. With this assumption, differences in behaviors of users at the exhibit in the different evaluation rounds can be assumed to be due to the changes made to the exhibit. This assumption was accurate as group type ($\chi^2 = 6.104$, $p = 0.107$, Table 3) and group size ($\chi^2 = 4.088$, $p = 0.130$, Table 4) show no significant difference between evaluation rounds. The majority of visitor groups observed were individuals or pairs. The distribution of groups in each group type is fairly consistent, but the majority of Individual Adults occurred in the Fall and the majority of Multi-generational groups occurred in the Winter (Fig 14). Even with the almost 30% change in these two group types, group type across evaluation rounds was not statistically significant. Since these two types of group demographics between the two

evaluation rounds show no significant differences, we will collapse them for further analysis of common behaviors exhibited by all users combined, as well as for a comparison between group sizes and types.

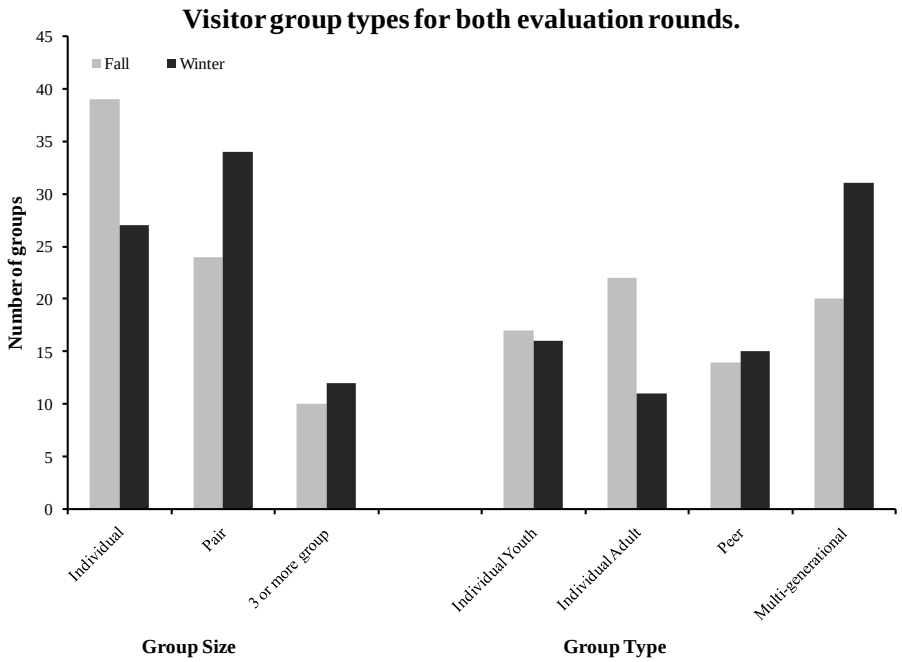


Figure 14. Histogram of group demographics for the fall and winter evaluations.

Coding and categories for first visits, total visits, and time spent

We will first examine how the exhibit was used by the different groups by identifying baseline, overall for all visitors combined, focusing on three factors: the zone in the exhibit visited first, the zones in the exhibit visited over the course of its use by each group, and the total time spent at the exhibit.

Where a user visits in the exhibit is documented in two ways: the place of their first visit (First Visit), and the zones visited during their entire time of use (Total Visits). Figure 15 shows that the levels of the exhibit are grouped into four major zones: Intro, which is the home and two intro pages; Info, which consists of the

estuary and LOBO pages; Easy, which is made up of the two levels in the first column on the second intro page, Levels 1 and 2; and Hard, which is made up of the three levels in the second column on the second intro page, Levels 3, 4, and 5. The visitors included in this analysis are those who started with the home page and subsequently visited the intro pages; visitors who started their interaction somewhere other than the home page are in the minority and are not part of the most common navigation route through the exhibit, and are excluded in further analysis.

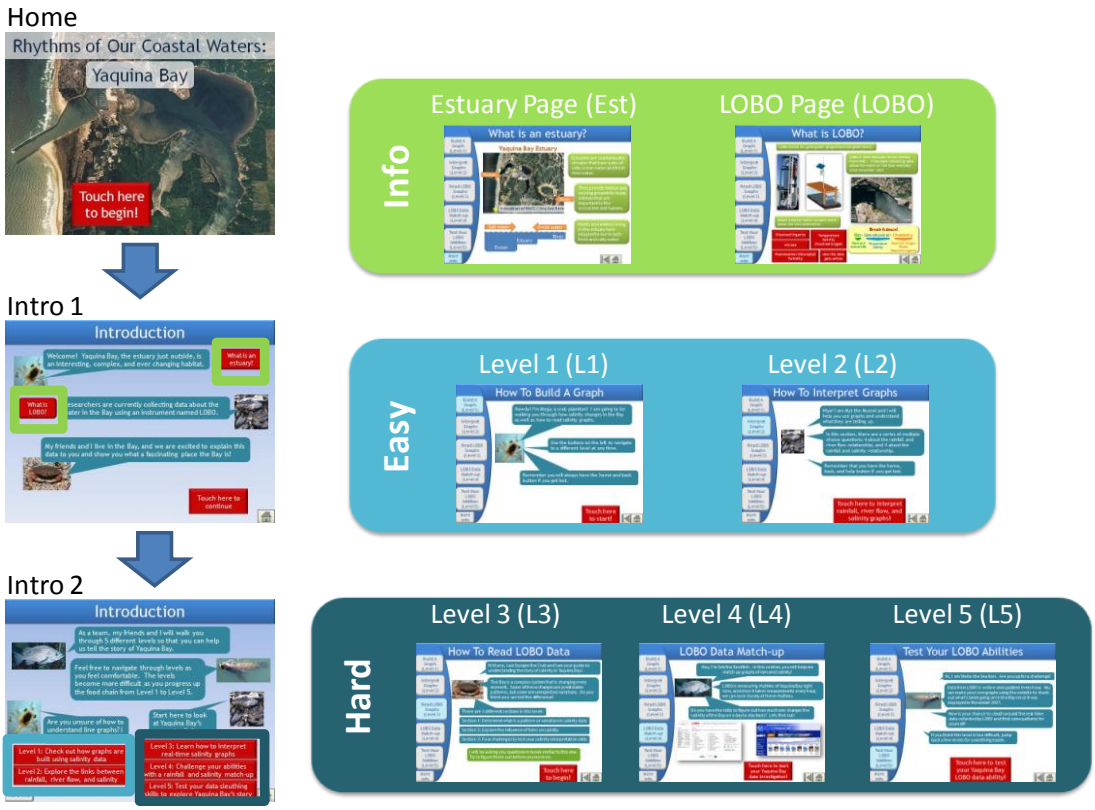


Figure 15. This diagram illustrates the pages and levels of the exhibit included in each exhibit area category. The home, Intro 1 and Intro 2 pages are included in the Intro Only or Done categories. The Info area includes the Estuary and LOBO informational pages, as accessed from Intro 1. The Easy area includes Levels 1 and 2, which are the two levels grouped together in Intro 2 on the left. The Hard area includes Levels 3, 4 and 5, which are the three levels grouped together in Intro 2 on the right. The buttons to access the different levels in Intro 1 and 2 are outlined with the corresponding color of the area boxes on the right of the figure.

First visit

A user's first visit falls into one of the four zones previously mentioned. Visitors can end their interaction before visiting any of the info pages or Learning Levels, or Levels 1-5, thus falling into the Intro Only, or Done, category. The visitors who go to another part of the exhibit from the intro pages fall into one of three categories, Info, Easy, or Hard. Visitors access the two info pages from the first intro page, and the Easy and Hard zones from the second intro page. We are interested in the first zone a user visits since this could be the result of the way the exhibit is introduced and presented. There is also potential that the zone they first visit could influence how much time they spend at the exhibit and their trajectory through the exhibit. Because there are links to the info pages in the intro, they are included in this analysis to determine if they are part of a common navigation path.

Overall visit paths of the first zone visited after viewing the Home and Intro pages indicate that visitors visit all zones of the exhibit equally (Fig 16). Overall, 87% of visitors started at the Home page then visited the Intro page, making this the most common entry point into the interactive exhibit and a control for the beginning route of navigation which facilitates direct comparison of visitors since the majority of them have this commonality between them. Of the four zones of the exhibit, Easy, Hard, or Done, where visitors left after the Intro zone, each had 21% of visitors start in that zone, and Info had 19% of visitors start there.

Total visits

A user's total visits during the time of their use of the exhibit include the zone of their first visit, as well as any other zones they go to after that first visit. For this analysis, visiting the info pages is not taken into consideration as we are only interested in how the visitors use the Learning Levels, or Levels 1-5, on the whole.

Figure 16. The first visit paths to general exhibit areas for all observed visitors. The numbers on either side of the Home box is the total number of visitors in the observation group for fall (green) and winter (orange). The percentages are the percent of all the visitors (fall and winter combined) that followed that visit path, and the arrow thickness corresponds to that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path.

The info pages are only supplementary to the Learning Levels, have information repeated from the posters, which are not included in any analysis, and do not directly support learning in regards to RTD graph interpretation since they are not an interactive level. Because of this, users are grouped into visiting Intro only (groups that are in the Intro group in the first visit are the same groups in this Intro only category), Easy only (groups who only visited Level 1 and/or 2), Hard only (groups who only visited Levels 3, 4, and/or 5), or Easy&Hard (groups who visited at least one of the Easy levels and one of the Hard levels). Again, only groups that started at the Home page were included in this analysis.

The total zones visited during a group's exhibit use include the zone visited first, as well as all the other zones visited subsequently. When all groups observed are combined, there is an almost even distribution of the number of visitors that visit Easy (21%), Hard (23%), or Easy&Hard (23%) over the course of their entire use of the exhibit; however, the largest number of visitors (29%) did not visit any of the learning

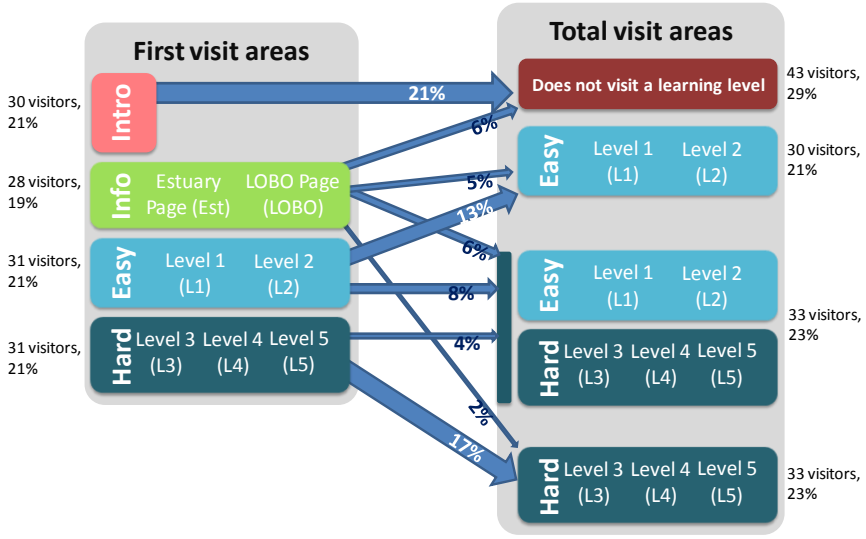


Figure 17. Visitor distribution from the area of the first visit to the areas included in the group's total visits. All percentages are out of 146, so are representative of the percent of groups out of the total observed groups that followed that first to total visit path. The total number and percentage for each first and destination-based total visit area are included on the left (first visit) or right (total visit) side.

levels, (Fig 17). It is inherent in the first visit categories that all the 21% of visitors in the Done zone do not visit a Learning Level at all since they leave the exhibit after the Intro pages, and this percentage increases due to visitors that visit Info pages first and then leave without going to any Learning Level. However, visitors who visit Info, Easy or Hard first provide themselves with an opportunity to stay within that exhibit during their entire use of the exhibit, or can choose to go to other zones in the exhibit.

For path-based total visits, besides the 21% of visitors that visit Intro Only and do not visit a Learning Level, the two most common first visit to total visit pathways for all the visitors was a first visit to Easy and stay in Easy Only or a first visit Hard and stay in Hard only (Fig 17). The paths from a first visit to Info to total visit to No Learning Levels, Easy Only, Easy&Hard, and Hard Only are fairly similar and small, so only the pathways from Easy and Hard as a first visit will be examined in more detail. Although it is not significantly different (Table 5, $\chi^2 = 2.82$, $p = 0.093$), a

Table 5. Chi-square analysis of visitors staying or visiting other levels after a first visit to Easy or Hard

	First Visit Easy	First Visit Hard	X^2	p-value
Stayed in same area	61.3%	80.6%	2.818	.093
Visited other areas	38.7%	19.4%		

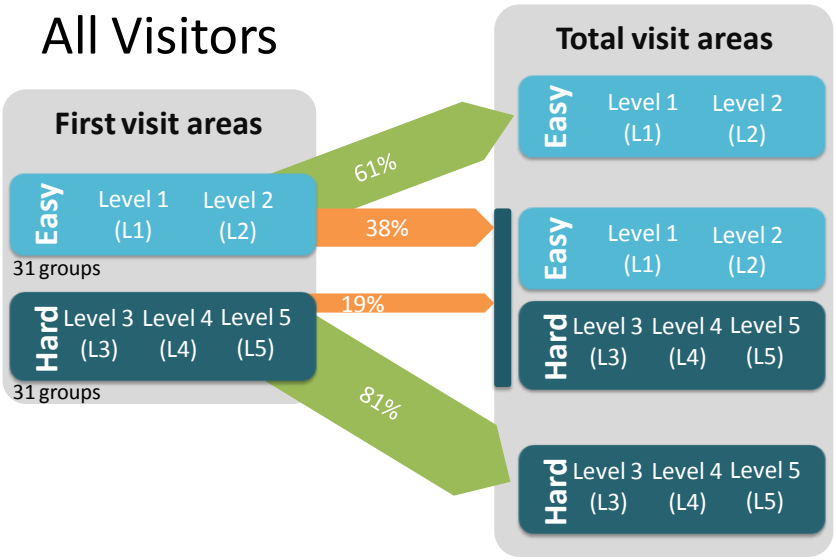


Figure 18. Path-based total visits in the Learning Levels. The group number under each first visit zone is the total number of groups. Arrows are variable by percentage, and the green:orange represents the fall:winter visitors.

greater percentage of groups that started in Hard stayed in Hard (81%) than those who started in Easy and stayed in Easy (61%); the other groups, 39% of Easy first visits and 19% of Hard first visits, visited at least one level from the other zone (Fig 18).

Time

Total time spent at the exhibit was coded into three categories, 0 to 1 minute, 1 to 4 minute, and more than 4 minutes. The 1 minute cutoff was determined from

literature, which is the upper most boundary of the average time visitors tend to spend at interactive science exhibits on the whole, and the 4 minute cutoff was carried over from the evaluation interview time cutoff. The predicted distribution of visitors within these three categories is that the majority of visitors will fall in the 0 to 1 minute category with a decreasing trend with the least amount of visitors in the more than 4 minute category.

When combined, the overall total time spent by all the observed visitors generally fits in the expected decreasing distribution trend. The greatest percentage of visitors, 44%, spent less than 1 minute at the exhibit, with 38% spending 1 to 4 minutes, and 18% spending more than 4 minutes at the exhibit (Fig 19). The average time spent at the exhibit was 2.5 minutes, with the maximum time spent, which occurred in the fall, as 22 minutes, and the minimum time spent being 6 seconds.

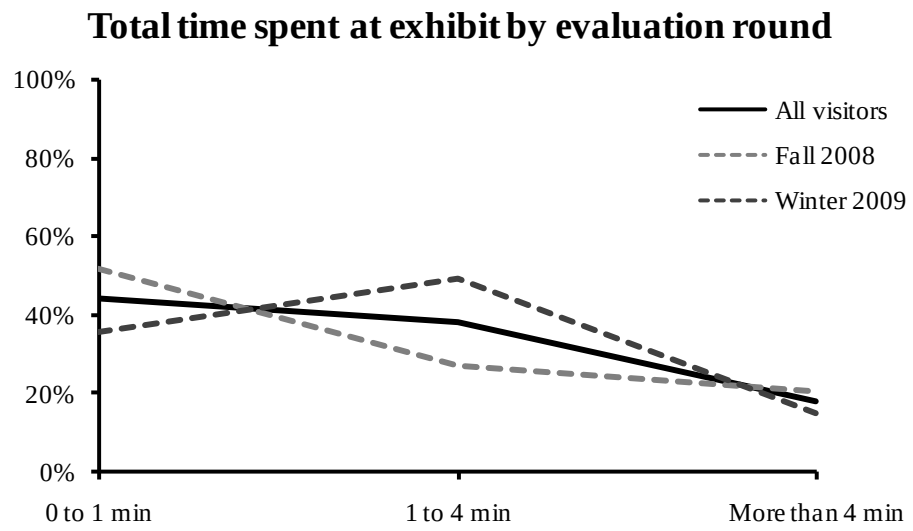


Figure 19. Total time spent at the exhibit in the fall and winter.

Talk

Visitor talk was categorized into reading out-loud, asking a question, making a statement, and any type of talk. Each instance of talking, reading, questioning or

making a statement was counted once for each group. Where any text was read verbatim from the exhibit slides, this was coded as Reading out loud. Asking a question ranged from asking a clarifying question to a peer, or asking a leading question to a child, and sometimes led to a discussion between visitors. This type of question initiated discussion was coded as a question. Any discussions not initiated by a question were placed under the statement made category. Since not all groups engaged in talk, the any type of talk category was used to determine how many groups engaged in at least one type of talk. To measure the relative complexity of the talk, groups were also coded into how many different types of talk they engaged in: none, one, two, or three. The following example group engaged in all three types of talking:

> Adult male, 55-65 years old: What is salinity?
> Child female, 5-10 years old: The saltiness.
> Adult: What is that called, when there are 2 axes?
> Child: A graph.
> Child then proceeds to read the text from the slide (Level 2). When done reading, the adult walks the child through how to choose the correct multiple choice answer by first narrowing the answers down to the most plausible ones.

In the first part of the interaction, there is a question and answer sequence, which is coded as a question. The middle part is coded as read out-loud, and the last part of the adult's explanation is coded as a statement. Types of talk were coded simply by presence or absence (as yes or no), so the number of times a group engaged in any given type of talking is not reported: even though the example group asked two questions, they are only coded with a yes for asking at least one question.

Examples of visitors' interactions coded as questions:

Group A:

> Teen to adult female, 15-25 years old: Do *you* know what an estuary is?
> Adult male, 55-65 years old: (while pointing at diagram) Where the river and the ocean meet.

Group B:

Male child, 5-10 years old: What is that word? (pointing to screen)
Male adult: (reads) "Biogeochemical" (continues to read text from the screen out-loud)

Group C:

Adult male to male child, 3-5 years old: (looking at picture of Bay on the home page) Where's the ocean? (after child points) No, that's where they mix together…this light stuff is the sand on the beach.

Group D:

Adult female: How salty do you think [the ocean is] going to be if 35 [psu] is here and 0 [psu] is here? (pointing to screen)
Male child, 5-10 years old: I'm guessing it would be lower.
Adult female: Correct!

Group E:

Adult female to adult male, both 60-70 years old: I don't have enough information to answer that? The only thing I can think of is more water- more saltwater enters and increases salinity, so freshwater decreases.

Adult female to adult male (same as above): A lot less salt, salinity is lower, so maybe more rain? (goes to next slide with answer on it) Haha! I'm right!

Examples of visitors' interactions coded as statements:

Group 1:

Adult male, 35-45 years old, to adult female of similar age and male child, 5-10 years old: Looks like [river] discharge follows rainfall.

Later, Adult female to group: It didn't like our answer- no, we got it right.

Group 2:

Adult female to female child, 3-5 years old: These aren't games, it's a learning program. Let's go do something more you.

Group 3:

Adult male, 50-60 years old, to male and female children, both 5-10 years old: Look, it says "Touch here to begin". It just asks you a bunch of questions, it's probably above you.

Group 4:

Adult female, 30-40 years old, to female child, 5-10 years old: (In response to

an answer on the screen) 26 [psu], it's not much less. (Adult continues to point at the graph and explains how salinity changes over the year.

Group 5:

Adult male to female and male children, 5-10 years old: Look, a plankton!

Overall, 29% of all 146 visitor groups (including individuals) engaged in any type of talk. When individuals are removed, 73% of visitor groups engaged in some kind of talk. Because of the expectation that individuals will not talk out-loud during their interaction with the exhibit, they are removed from further analysis and discussion. Out of all 80 non-individual groups, 25 groups (31%) read out-loud from the slides, 18 groups (23%) asked a question or started a discussion with a question, and 35 groups (44%) made a statement or started a discussion with a statement, which makes making a statement the most frequent type of talk. Forty groups, or 50% of non-individual groups, engaged in at least one type of talk. Among those who did talk, the largest number of visitors, 16 (20%), engaged in 1 type of talk. Nine groups (11%) engaged in 2 types of talk, and 14 (18%) of groups engaged in 3 types of talk. The overall trend along the increasing spectrum of talk complexity that describes the visitor distribution is a decrease in groups from no talking to 2 types with an increase to 3 types of talking.

Besides the general trends of all visitors, other trends are seen when comparing talk of visitors using V2.0 of the computer in the fall (34 non-individual groups), and talk of visitors using V3.0 of the computer in the winter (46 non-individual groups). In comparing the types of talk, fewer non-individual visitors in the fall engaged in reading out-loud or asking a question than in the winter, whereas more fall visitors than winter visitors engaged in making a statement or engaging in any type of talk (Fig 20). Making a statement was the most common type of talk for both the fall and the winter.

In looking at the change in talk complexity between fall and winter, the general trend of decreasing percentages from no talking to 2 types with an increase to 3 types is upheld in both evaluation rounds (Fig 21). Even though both fall and winter have

the same overall trend of the groups that actually engaged in at least one type of talk the greatest percentage in the fall engaged in 1 type of talk and the greatest percentage in the winter engaged in 3 types of talk, indicating a shift to greater talk complexity from fall to winter. This is reflected in the percentages of visitors from each evaluation round that appeared in each talk complexity type: 1 type of talking decreased from fall to winter, the percent of groups that engaged in 2 types of talk was relatively similar in fall to winter, and 3 types of talking increased from fall to winter. However, the percent of non-individual groups who did not talk increased from fall to winter, which is disparate from the overall increase in talking complexity trend.

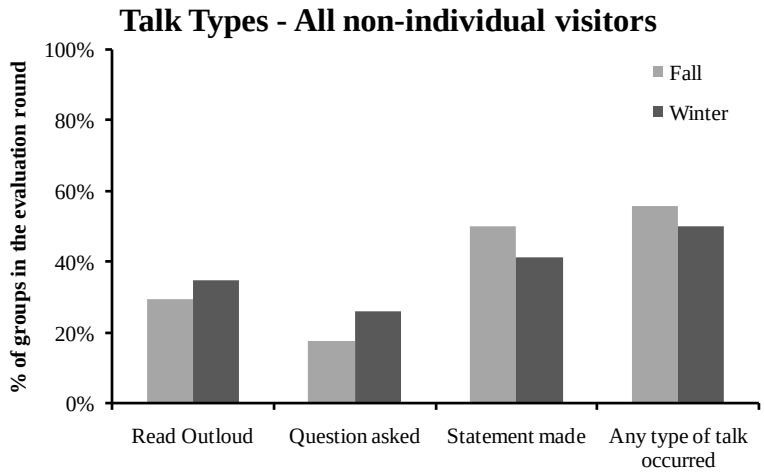


Figure 20. Percentage of all non-individual visitors in the fall (34 groups) and the winter (46 groups) that engaged in talk.

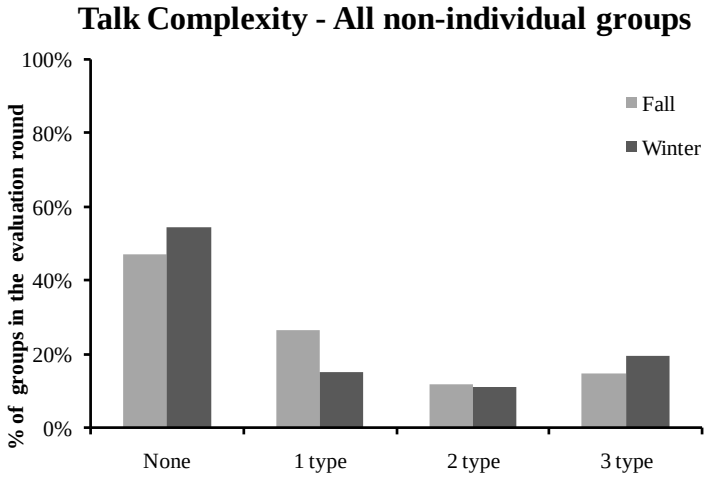


Figure 21. The talk complexity for all non-individual groups in the fall (34 groups) and winter (46 groups) evaluation rounds.

Design Claim 1: The technology and language of the exhibit is accessible and understood by visitors of all ages

Since this is the first exhibit of its kind, the first concern is if the design of the exhibit and use of touch screen technology is actually appropriate and accessible for science center visitors. This claim is focused on showing that these overarching design assumptions are true, first through visitor feedback gathered during the interviews, then secondly through observation data comparing first visits in the fall and the winter.

Design elements and use of technology

This section is based on feedback from interviews. Groups that spent more than four minutes at the exhibit were interviewed about their experience at the exhibit, what they found challenging or would want changed, what they liked or made it easy to understand, and what they learned or new information they didn't know before. For this claim, we will only be examining the responses to the first two questions, what the

visitors didn't like and what they did like. Out of the 26 groups that spent more than four minutes, 23 groups were interviewed. Of these, all group type and size categories are represented, as well as an age range from elementary school age youth to senior citizens. The groups that were interviewed were 2 individual youth; 5 individual adults; 9 peer groups, 7 of which were adults and 2 of which were teen groups; and 7 multi-generational groups, with a youth age range from toddler to middle school. Since age is the real factor here, we will break the group types down by age (child, teen, adult, multi-generational) with no consideration of the social structuring of group size or if they were an individual or part of a peer group. The multi-generational group type is maintained to signify that multiple ages were included in that group, even though typically it was either the youth or adult, not both, that was the dominant answer-provider during the interview.

The responses to the two questions of interest were coded into three categories:

- Interface- general layout, navigation tools (physical and programmed) and labels
- Content/information- wording, difficulty level, general understanding of instructions and how to use exhibit, in general the information presented
- Nothing

Some comments from groups had multiple codes applied to them (i.e., made comments about both the interface and the information content), so the numbers are representative of how many groups made that type of comment and not the total number of groups interviewed.

What users found challenging or didn't like

Table 6. Coded visitor comments in response to the questions a) was there anything challenging to use or understand in the exhibit and b) was there anything that they liked about the exhibit?

	Child	Teen	Adult	Multi-gen	Total
Challenging					
Interface	1	0	2	2	5
Content	0	0	3	2	5
Nothing	0	2	6	3	11
Liked					
Interface	0	3	7	2	12
Content	1	1	10	6	18
Nothing	0	0	1	0	1

Only about half the groups found some element of the exhibit to be challenging to understand or use, or suggested changes be made (Table 6). Half of the groups that did identify a point of confusion made comments about the interface, with contributions from almost all the group types. In the fall, three comments that required minor fixes were that some pages were overloaded with text (youth), which was a function of the animations not working for every visitor during the fall, and confusion about either how to use the navigation buttons (older adults) or about the text on the navigation buttons (multi-generational, adult). These were a priority modification for the next version as outlined in Chapter 3, and no groups in the winter made any similar comments about these issues.

The last interface comment was by an adult in a multi-generational group who believed that the touch screen should be the secondary mode of interaction with the computer since most young children have a good grasp on how to use the mouse. Informal observations made on V1.0 of the computer, that did not have a touch screen, suggested that adults were more likely to walk by the exhibit without stopping and that children would run across the room to just "click around" on the computer. Because of the apparent lack of interest by the adults, a touch screen was used to break down any constraints that a mouse-only driven interaction would provide. A mouse was included as part of the touch screen exhibit as a back-up device since the check boxes on the website are very small and we anticipated would be problematic with a touch

screen only. Observations of V2.0 and V3.0 of the computer indicated that no groups had difficulty with operating the exhibit either through the touch screen or mouse.

Comments about the content either offered concrete solutions, or more hypothetical opinions. A few of the comments with concrete solutions were by adults and related to wanting more background information, content, and vocabulary definitions, (e.g., PSU). One group specifically asked for information regarding why scientists are collecting these data and how they use it, which is explained in detail on one of the posters which is situated just to the right, behind the computer monitor. This shows that groups may not refer to the posters for background information, so it cannot be assumed that visitors will find the information if it is on the posters only. The information about the use of the data was not included in any of the computer exhibit versions due to time constraints; however, an explanation of what PSU is was developed for V3.0. Lastly, one older adult group in the fall didn't understand Level 5, and even though they read all the text on the page, they couldn't figure out what they had to do. This comment is also supported by observation data where visitors did not go online to look at the data, which resulted in a more substantial modification of Levels 4 and 5 in V3.0 of the exhibit, as outlined in Chapter 3.

The last few comments from adults relate to the difficulty level of the exhibit for children. One adult in the fall said that rainfall and salinity patterns didn't surprise him but thought that they would be too subtle for younger folks, and another in the winter thought that 10 year olds would not be able to understand the graphs since it is not taught in schools. However, the next adult interviewed thought that there was nothing challenging to the exhibit content and that it seemed to be made for kids. Many visitors did ask what age group the exhibit was designed for, and after getting the response that it was intended for all ages, would give their opinion of whether it was more appropriate for adult levels of knowledge or if it was more appropriate for kids.

What users liked or found easy to use

The comments about elements in the exhibit that visitors like or found made using the exhibit easier also included comments about the interface and content (Table 6). Comments about the interface came from almost all age types and out-numbered the combined number of all responses made about what they didn't like in the exhibit. All age types responded positively to the touch screen monitor and the interactive nature of the exhibit. Several especially liked the buttons, either to find more information, to choose an answer, or simply because the buttons said "Touch here to continue." Many commented on the overall look of the exhibit, the use of different colors for instructions and small text boxes, and the use of animation that made the exhibit look "very slick." Others commented on the types of activities presented, with one teen group especially enjoying the multiple choice part since they could choose their answers. A child in a multi-generational group really liked the "mentally choose" section in V3.0's Level 3, and an adult pair appreciated how the levels increased in difficulty. All of these comments indicate that the exhibit interface was a success, especially the touch screen monitor to interact with the exhibit and the layout of the text and use of buttons.

The positive comments about the content of the exhibit out-numbered the comments about the interface, and all groups made at least one content-related comment concerning what made their interaction with the exhibit easy. There are three major themes to the comments about the content, the clarity of the wording, the layout and presentation of information, and the actual information. The feedback about the clarity of wording referred both to the instructions given and the questions asked. Both teens and adults found the instructions were clear and easy to understand for any knowledge level, and multi-generational groups and adults found that the questions were just difficult enough that they were not boring. Although some of the questions were challenging, visitors commented that the wording made it easy to understand when they "stopped to think about it." Several visitors made comments

that the exhibit and the content were easy to understand because they were laid out well, in organized categories, and presented in a step-wise manner that kept touching back on the same themes. Lastly, there were comments about the actual information content. Many adults were very interested in the supplemental information presented in the Estuary and LOBO pages, and multi-generational groups expressed interest in the data and science content of the exhibit. One youth who was part of a multi-generational group was particularly excited that she was able to answer one of the questions in Level 3 of V3.0 correctly, and one adult peer group appreciated having an exhibit at their advanced level that they could learn from. Lastly, one youth was so excited by the exhibit in the fall that she stayed at the exhibit for 20 minutes to see if she could do all the levels.

Conclusions

Both interviews and observations are necessary for conducting effective evaluations of exhibits. The four minute mark was chosen as a cut off for recruiting visitors for interviews because that is the amount of time that it seemed to take visitors to go through a level or to look around the exhibit and then engage in a level in a focused way. Interviews were a crucial element of the evaluation: without talking to one particular older adult peer group we would not have known that they didn't know what it was asking of them based on just observations. Additionally, without interviews, the evaluation of the small scale design details that are related to navigation or instructions used widely throughout the exhibit and their effects on behavior would not be easy to tease out. The interviews allow a greater insight into what was an affordance for users and what was a constraint.

Based on changes made to the exhibit from fall to winter, positive changes were made that improved the usability of the exhibit. The goal of making navigation and instructions more explicit was achieved since more visitors during the winter than

the fall responded with “Nothing” to the question asking if there was anything they didn’t like about the exhibit.

Changes in introductory text effectively changed visitor use

The method of design-based research is that the users, through their interaction, will assist the developer in designing a tool that most users will use in the way the developer intended. The iterative evaluation process conducted for this exhibit was to accomplish just that, in hopes to direct visitors to the level most appropriate to them and make any additional background information easy to find in logical places. The changes made to the exhibit from Version 2.0 to Version 3.0, as well as some of the qualitative results of visitor use, are outlined in Chapter 3; however, in this claim a few quantitative results are outlined to support the continued use of an iterative prototyping process in exhibit development. Changes made to wording in the Intro pages and the corresponding changes in where visitors visited first are presented.

After the first evaluation round, we noticed that the first visits after the Home and Intro pages were not occurring in a way we expected. We assumed that the knowledge level of the majority of visitors would be appropriate for the exhibit levels in Easy, and thus hypothesized that the majority of visitors would visit Easy first. However, we saw that more visitors left the exhibit (Done) or visited Hard first than a first visit to Easy or Info. As discouraging as this was, a more encouraging pattern was seen in the first visits to individual levels since the highest percentage of users visit the Estuary page and the next highest visit L1, but we also saw that the third most popular first visit level was L5, the hardest level in the exhibit (Fig 22). Because of the visit pattern seen to the zones and levels, the wording on the level buttons in the second Intro page (Table 7), as well as the text about the LOBO instrumentation on the first Intro page (Fig 23), was made to be less ambiguous on V3.0.

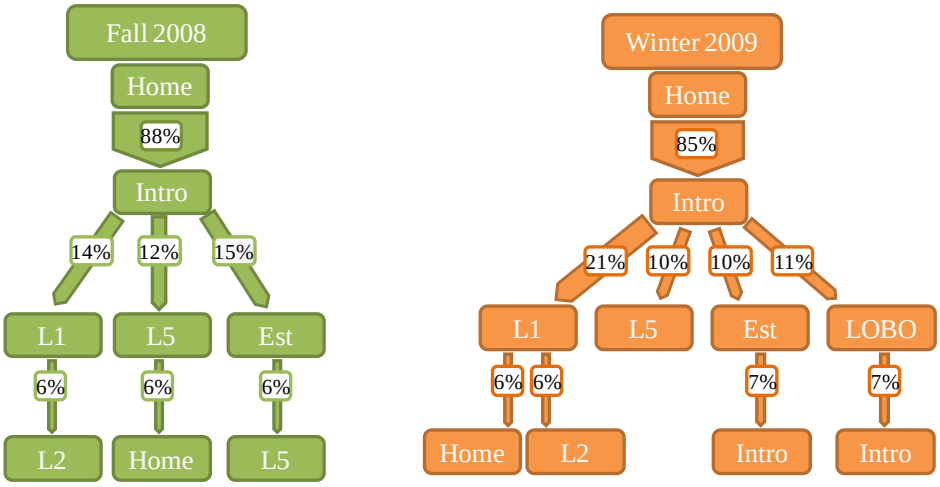


Figure 22. The first visit paths to specific exhibit levels during the fall and winter evaluations for all observed visitors. The percentages are the percent of all the visitors during that evaluation round (n=73 for each) that followed that visit path, and the arrow thickness corresponds to that percent. Only the paths from Intro to the first level visited with greater than 10% of visitors were included.

Table 7. Changes in navigation button text between all 3 computer versions.

	Version 1.0	Version 2.0 (Fall 2008)	Version 3.0 (Winter 2009)
L1	Level 1: How do we build graphs from data?	Plankton level: How do we build graphs from data?	Level 1: Check out how graphs are built using salinity data
L2	Level 2: Interpreting historical graphs	Mussel level: Explore the links between rainfall, riverflow, and salinity	Level 2: Explore the links between rainfall, river flow, and salinity
L3	Level 3: How to read graphs of LOBO data	Crab level: How to read real-time data salinity graphs	Level 3: Learn how to interpret real-time salinity graphs
L4	Level 4: Investigating rhythms using LOBO data	Rockfish level: Investigating rhythms using real-time data	Level 4: Challenge your abilities with a rainfall and salinity match-up
L5	Level 5: Test your LOBO data abilities!	Sea lion level: Discover Yaquina Bay's story	Level 5: Test your data sleuthing skills to explore Yaquina Bay's story

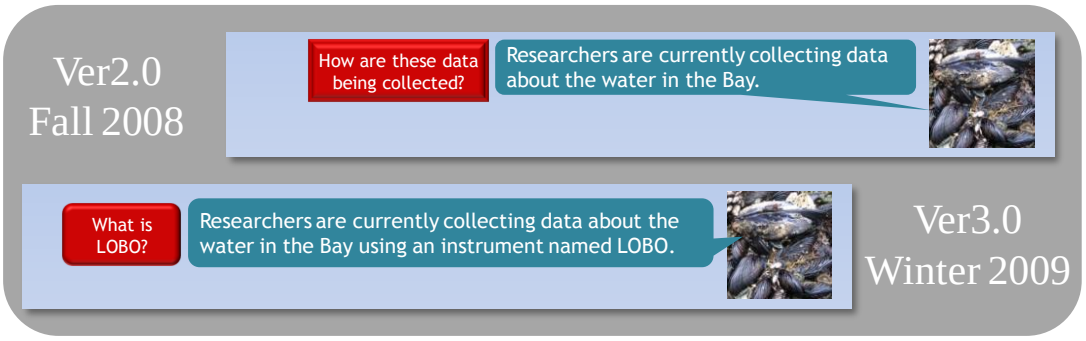


Figure 23. Text from the first Intro page in V2.0 and V3.0.

The results seen in the visitor first visits using V3.0 in the winter were a step in the right direction with an overall increase of users visiting Easy first and a decrease in visitors leaving the exhibit (Done) after the Intro pages . This first visit change was also reflected in the levels, with a large increase of users visiting L1 and the LOBO page first and a slight decrease in users going to L5 first (Fig 22). The increase of the visits to LOBO from 3% of visitors in the fall to 11% of visitors in the winter is significant ($\chi^2 = 3.865$, $p = 0.049$), and can be directly linked to the minor text alteration of only a few words that enticed more visitors to push the button. However, the other changes in visits, though not significant, are not as straight forward to explain. The goal to significantly decrease the number of visitors going to L5 first in V3.0 was not achieved, but the goal to increase the number of visitors to L1 was, albeit not significant, from 14% of fall visitors to 21% of winter visitors. Coupled with this observation is the significant decrease in visitors that visited only the Home and Intro pages from 23% of visitors in the fall to 10% of visitors in the winter ($\chi^2 = 4.986$, $p = 0.026$), which combined suggests that the text in V3.0 was more focused and less ambiguous in its intention. This shows that modifications in an exhibit doesn't necessarily have to be a large overhaul of design or presentation, small

changes in text alone can help guide visitor use in the direction that the developer seeks.

A final thought about the importance of words is based on an informal observation made early in the fall evaluation round. Unbeknownst to the developer the power or strength of words, even though there was a sign on the side of the monitor that indicated that it was a touch screen, most to all visitors in the first day or two of the fall evaluation used only the mouse, which was supposed to be the secondary method, to interact with the exhibit. Unwittingly, the developer had made the initial text on all the navigation buttons in V2.0 of the exhibit use the word "click", as in "Click here to continue", but as soon as "click" was changed to "touch", the touch screen became the primary method of exhibit interaction by most of all of the visitors for the rest of the fall evaluation, as well as the winter evaluation. It is important to consider words and their usage when creating directions and instructions for these types of educational tools and remember what meanings they have to a general audience.

Design Claim 2: Group size and group type influence use patterns and time spent at the exhibit

This section outlines use of the exhibit by the different group types through first visits, total visits, and time spent. Comparisons of use will be made both between specific groups and overall use, and also between specific groups and other groups.

Use of the exhibit by different group sizes

First Visits

The majority of visitors in each group size type followed the Home to Intro pages entry point. Seventy-nine percent of all 66 individuals, 86% of all 58 pairs, and 82% of all groups of 3 or more followed this entry point, thus making it the most common entry point for all visitors. After viewing the intro pages, the most common first visit zone for Individuals is Done, for Pairs is fairly even visits to Easy, Hard, and Info, and for Groups of 3 or more is evenly distributed between Done and Info (Fig 24). Individuals and Groups of 3 or more share Done as a common first visit zone, which means that the largest percentage of these groups left the exhibit after seeing just the Home and Intro pages; however, the Groups of 3 or more also have an equally high percentage of visitors visiting Info first, which, although it is not a Learning Level zone, still holds information about the dataset and is the location to learn the definition of estuary, which was one of the noted "things learned" in Learning Claim 1 in Chapter 5. Groups of 3 or more and Pairs also share a common first visit zone, Info, but Pairs also visit Easy and Hard first just as equally as Info. Pairs are the only group size that visit a Learning Level zone first, and because of the almost equal distribution between the three first visit zones, no definitive conclusions can be made about the single most common first visit zone by pairs.

Total Visits

Total visits are examined in two ways, the first is the most common zone visited, including Done, during a groups entire visit (all total visits) (Fig 25), and the second is the most common zone visited that does not include Done (total visits in Learning Levels only) (Fig 26).

For individuals, the same first visit path to Done was again the most commonly followed out of all the total visit zones. However, when just looking at the total visit

zones for the Learning Levels only, the most common end point for individuals (17%) was Hard Only, a first visit for 21% of individuals.

For pair groups, even though the most common subsequent visit after first visiting either Easy or Hard was to stay in that first visit zone, the most common total visit zone for pairs was Easy Only. After a first visit in Info, 10% of pair groups then visited Easy, which combined with those that visited Easy first and stayed there, made

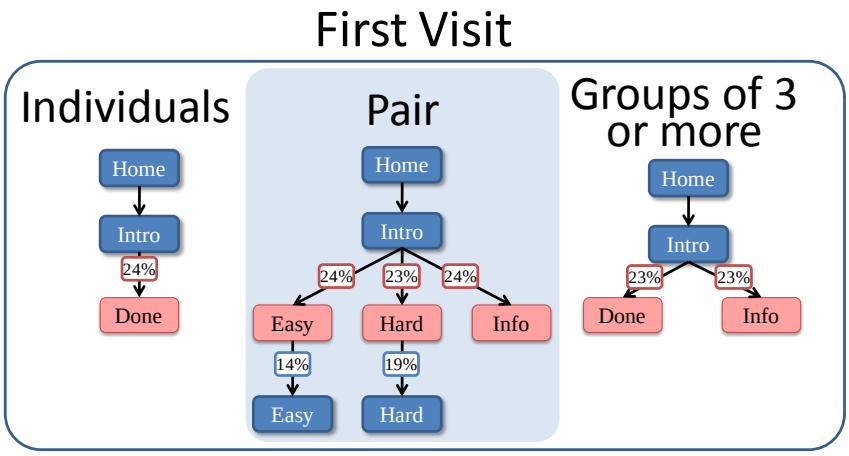


Figure 24. Most common first visit path for group sizes.

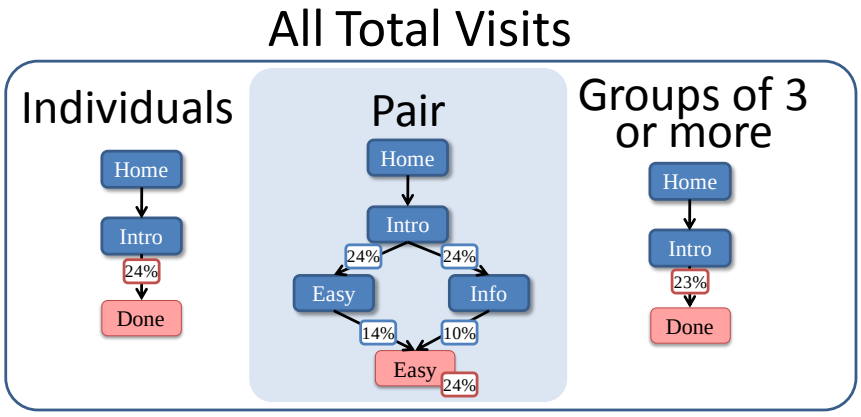


Figure 25. Most common destination-based total visit path for group sizes.

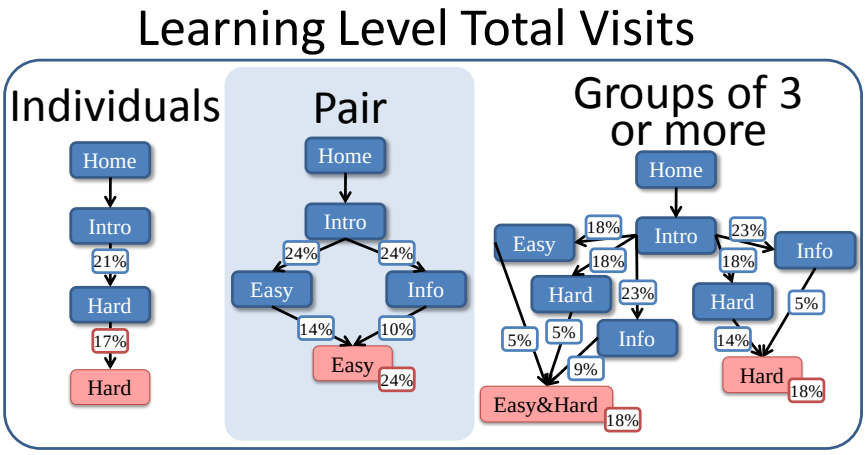


Figure 26. Most common destination-based total visit in the Learning Level zones for group sizes.

Easy the most common total visit zone for all Pairs. These total visit paths from Info and Easy to Easy Only was also the most common Learning Levels only total visit path for Pairs.

For Groups of 3 or more, the most common total visit zone is Done, with 23% of groups leaving after the Intro pages. Looking at the total visit zones in Learning Levels only, Groups of 3 or more show a much different and complicated pattern than the other two groups. The two most common total visit zones in Learning Levels is split equally between Hard Only and Easy&Hard, with visitors accessing Hard Only from two first visit zones and Easy&Hard from three first visit zones. The majority of groups that visit Hard Only are from a first visit to Hard, with a small percentage of visitors arriving from Info. Groups that visited Easy&Hard were more equally distributed from first visits in Easy, Hard, and Info.

Time

The total time spent at the exhibit by Individuals fits with the assumed decreasing trend of visitors as time increases, but time spent by Pairs and Groups of 3

or more does not fit this assumption. The greatest percentage of individuals spend less than 1 minute at the exhibit and the smallest percentage spends more than 4 minutes (Fig 27). For Pairs, on the whole the distribution of total time spent at the exhibit was a more flattened, normally distributed curve with the greatest percentage spending 1 to 4 minutes, and almost equal percentages in the two categories on either side. Groups of three or more had a more or less equal distribution amongst all three total time spent at exhibit categories, so no conclusions will be made about the amount of time Groups of 3 or more spend at the exhibit.

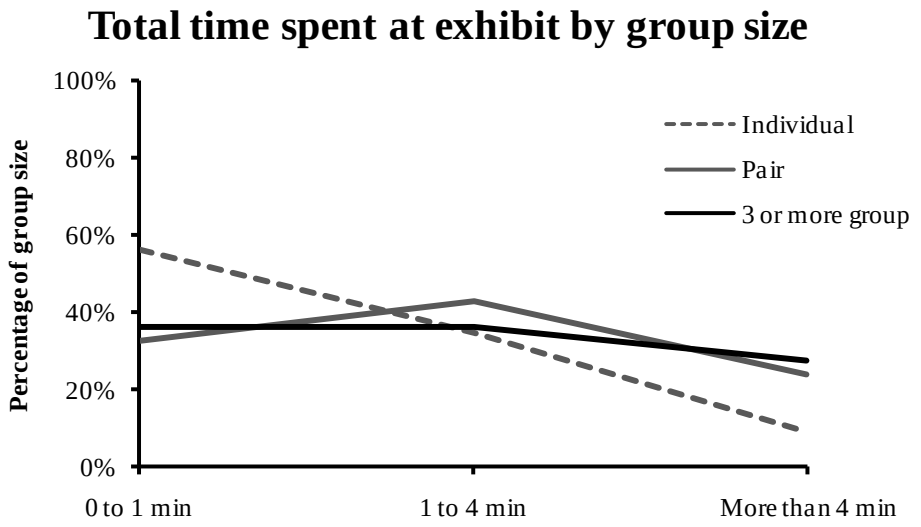


Figure 27. The percentage of groups within each group size that used the exhibit for under 1 minute, 1 to 4 minutes, or more than 4 minutes.

Summary of use by group sizes

Out of all the group sizes, Individuals have the least complicated visit patterns. As the figures demonstrate, the first and total visit paths of Individuals had no branching indicating that these groups have very similar use patterns and small variability from group to group. They also spent the least amount of time at the

exhibit out of all the other group sizes with the vast majority spending less than 4 minutes. The lower amount of time spent at the exhibit is explained by the fact that the greatest percentage of Individuals went to Done or left the exhibit after the Intro pages. However, within the Learning Levels the greatest percentage of Individuals is visiting Hard, which indicates that even though there is some percentage of Individuals going to a Learning Level, they aren't spending a lot of time there, and since the Hard levels are assumed to take more time, this suggests that Individuals are only casual visitors to these levels and not engaging in the activities.

Pairs have a difficult story to tell because they don't, on the whole, follow one distinct path like Individuals. Pairs have no first visit preference since there is equal distribution to Easy, Hard and Info; however, we can say that they are the only group size that did not have the largest percentage of groups visiting Done first, which indicates that Pairs are more willing than other groups to at least investigate and interact with the exhibit beyond just the Intro pages. We do see though, a preference in visiting Easy Only as a total visit, which is accessed almost equally from a first visit to Easy or Info, and with the largest percentage of groups spending 1 to 4 minutes at the exhibit, this indicates that Pairs are possibly engaging with the activities presented in Easy. This is further supported since over 25% of Pairs are spending more than 4 minutes at the exhibit and even though the smallest percentage of Pairs spend this much time, this shows that there are some factors at play that are engaging Pairs to stay for longer amounts of time than what was seen by Individuals. Elements in the exhibit could be engaging Pairs better than Individuals, or the presence of social interaction with another person could be lengthening the stay as well. Where the Individuals don't have another person that they are accountable to, Pairs may feel more pressure to stay longer if the other person in their group is showing interest in the exhibit. So even though Pairs do not follow one generalized path, they show indications that engagement with Easy and another person increases time spent at the exhibit.

Groups of 3 or more also are difficult to make generalizations about. Based on the most common first visits, which are to Done and Info, and all inclusive total visits, which is to Done, these larger groups don't seem to have too much of a story to tell at first glance. However, looking at the extremely branched total visit paths in the Learning Levels and the almost even distribution of groups in the three time categories, it becomes clear that once these larger groups get into the Learning Level zones, their usage patterns become interesting even though no generalizations can be made. We can make generalizations that Individuals are spending cursory time to just see what the exhibit is all about and then leave shortly thereafter, and Pairs have a tendency to converge on Easy and spend longer amounts of time at the exhibit. The difficulty in making generalizations about these larger groups could possibly be due to the number of people in these groups. Individuals only have themselves to consider when interacting with an exhibit, and Pairs only have one other person, which maybe introduces less interpersonal conflicts of interest while interacting with the exhibit than larger groups. We see this in these larger groups because where they start off having similar first and all total visit patterns as individuals, they ultimately end up having the most complicated Learning Level total visit pattern of all. With the combined information of equal groups falling within each of the three time categories and no one overall most common total visit area, it seems that the interaction of larger groups follow multiple interests and have no one characteristic.

Use of the exhibit by different group types

First visits

The most common entry point to the exhibit is visiting Home then Intro. Of the 33 Individual Youths observed, 64% followed this path, 94% of the 33 Individual Adults followed this path, 83% of the 29 Peer groups and 86% of the 51 Multi-generational groups followed this path (Fig 28). As for all combined Individuals, the

most common first visit of Individual Youths was Done, leaving the exhibit after the Intro pages. Individual Adults were different, however, with Easy as the most common first visit zone. The highest percentage of Peers visited Info first, and Multi-generational groups, like Individual Adults, visited Easy first.

Total visits

Again, total visits are described in two ways, one is inclusive of Done as a total visit (Fig 29), and one is for total visits to Learning Level zones only (Fig 30). The most common all inclusive total visit path for Individual Youth was the same as the most common first visit, Done. However, the most common total visit path that resulted in a Learning Level zone visit was Easy&Hard, with equal percentages of youths accessing it from Info, Easy, or Hard as first visits.

Even though on the whole the first visits of Individual Adults were different from both the total of Individuals and Individual Youth, total visits by Individual Adults looked more similar. The most common all inclusive total visit for Individual Adults was to Done, which is the same as all Individuals and Individual Youth. However, the most common total visit in a Learning Level zone was Hard Only, with the majority of adults who visited Hard first staying in Hard Only.

Peers are the only group that visited the Learning Level zone only for the inclusive total visit zone. The most common total visit destination for Peers was to visit Easy&Hard, with the larger percentage visiting Easy first and a smaller percentage visiting Info first; no groups that visited Hard first visited Easy&Hard as a total visit.

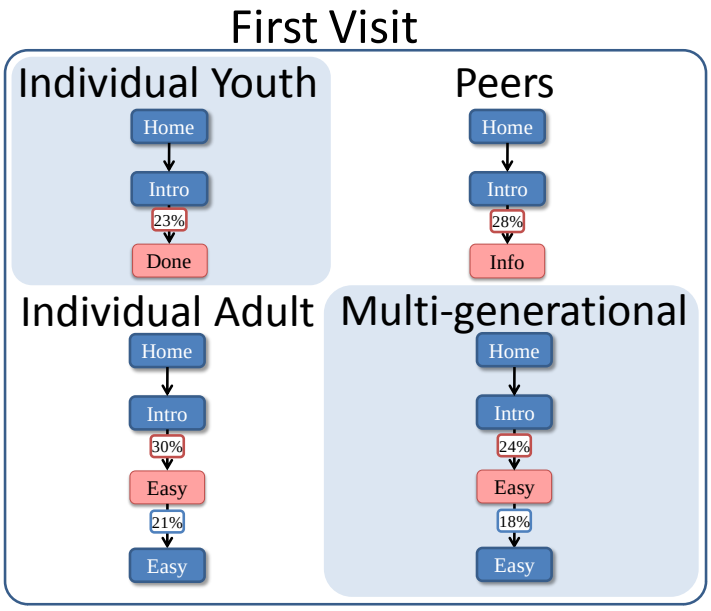


Figure 28. Most common first visit paths for group types.

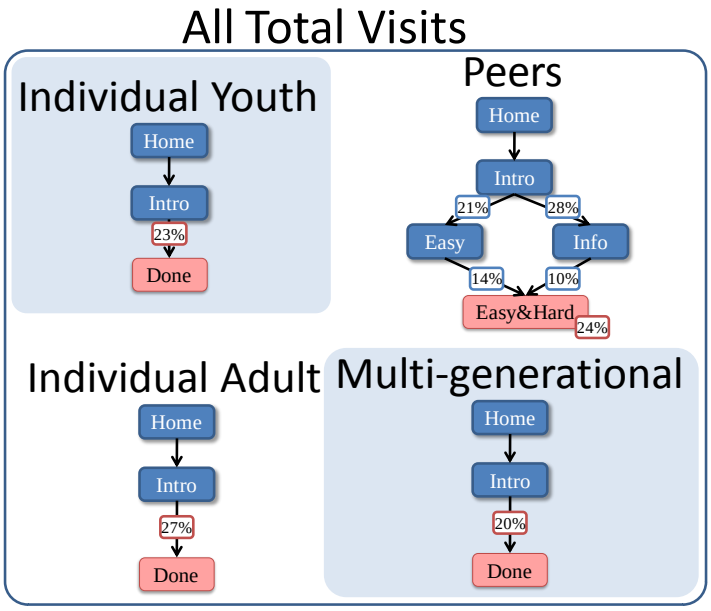


Figure 29. Most common destination-based total visit paths in any zone.

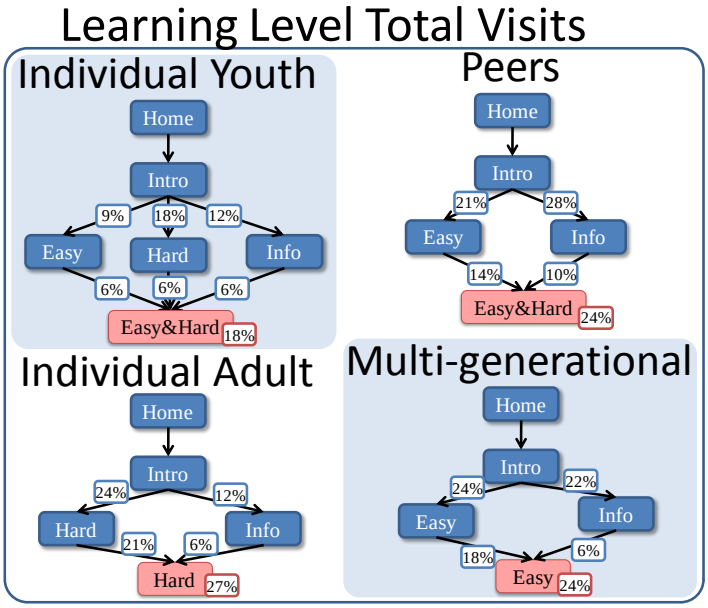


Figure 30. Most common destination-based total visit paths for group types in Leaning Level zones only.

Multi-generational groups have the same inclusive total visit as the two Individual categories, but a much different Learning Level only total visit. The greatest percentage of Multi-generational groups went to Done as the total visit, but for the Learning Level only zone, the greatest percentage of groups visited Easy Only. Similar to Individual Adult and Peers, the biggest percentage of Multi-generational groups that visited that zone in total also visited that zone first, which is in this case a first and total visit in Easy, but had a smaller percentage of groups that visited Info first before visiting the most common Learning Level zone.

Time

The distribution of total time spent at the exhibit by individual youth fits with the expected decreasing trend of visitors as time increases (Fig 31). The greatest percentage of youths, spent less than 1 minute at the exhibit and the smallest

percentage spent more than 4 minutes. Individual adults also show the expected decreasing total time distribution trend where the number of adults decreases as the amount of time spent at the exhibit increases with more than 90% of Individual Adult spending less than 4 minutes at the exhibit. However, time spent at the exhibit by Peer groups does not fit the expected trend: the percent of groups actually increases as the amount of time at the exhibit increases. The least amount of peer groups, 28%, spend under 1 minute at the exhibit, whereas 41% spend more than four minutes at the exhibit. Multi-generational groups have a different time distribution than all other groups since it neither decreased nor increases. It is not normally distributed either, though is more in that direction. The greatest percentage of groups spent 1 to 4 minutes at the exhibit with a larger percentage of groups in the under 1 minute category than the over 4 minute category.

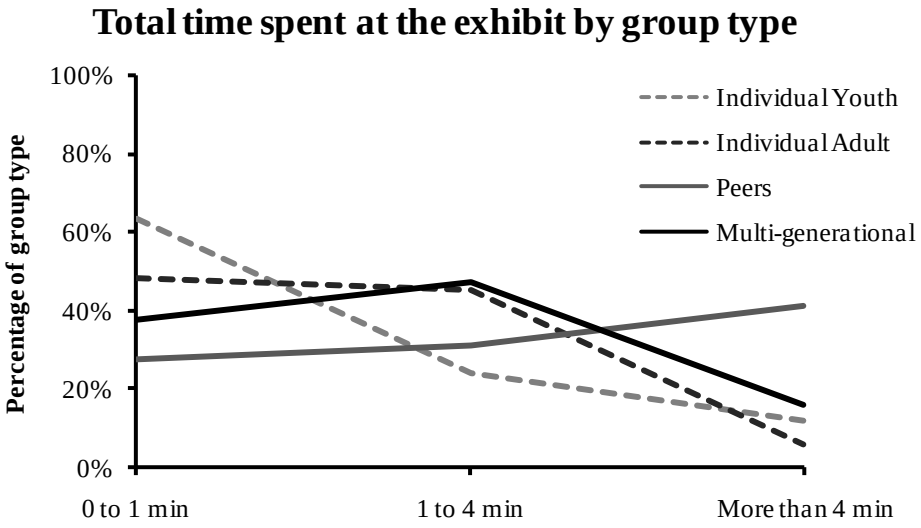


Figure 31. The percentage of groups within each group type that used the exhibit for under 1 minute, 1 to 4 minutes, or more than 4 minutes.

Summary of use by group types

As seen in the case of all Individuals combined, both Youth and Adult Individuals spent less time at the exhibit and have visit paths that are easier to generalize than the other groups. Individual Youth spend the least amount of time at the exhibit and have the most common first and all inclusive visit to Done, which explains why they spend a relatively small amount of time at the exhibit. The most common total visit destination within the Learning Levels is to Easy&Hard, but it is difficult to make conclusions about a common path taken since only a small percentage from three different first visit zones go to Easy&Hard in total. Also, the small amount of time spent at the exhibit indicates that even though these Youth are going to multiple levels, they are not engaging with the activities as intended. In contrast, Individual Adults are spending slightly more time at the exhibit and have Easy as the most common first visit zone. This shows a more focused use of the exhibit than Individual Youth, suggesting that the exhibit may not be appropriate for an Individual Youth without an adult to facilitate the activities. However, the most common total visit zone for Individual Adults is Done with the most common in a Learning Level zone being Hard Only. These three different visit paths make it difficult to determine the effect that first visits have on time spent, if any. It can be assumed that the visitors who leave after the Intro pages would spend the least amount of time at the exhibit, and also that Individuals in general would have a more focused use of the exhibit since they are only fulfilling their own interests. We see that even though the most common first visit is to Easy, that the most common total visit in a Learning Level is to Hard Only, which is difficult to interpret. It might be that Individual Adults have the knowledge and skills needed to engage in the activities presented in the Hard levels, but the smaller amount of time spent at the exhibit would indicate that this engagement is not occurring.

In comparison to Individual Adults and Individual Youth, Multi-generational groups had almost the same visit pattern as Individual Adults but spent a slightly longer amount of time at the exhibit. The first visit to Easy and a total all-inclusive visit to Done was the same as Individual Adults, but where Adults had a Learning Level total visit in Hard Only, Multi-generational groups had a total visit in Easy Only. This slight change in visits can be the explanation for the smaller amount of Multi-generational groups spending less than 1 minute at the exhibit, and an explanation for these groups to stay in Easy Only could be due to the presence of a youth in the group. A youth could be that focus factor that Individual Adults on the whole don't have that creates a commonality in all Multi-generational groups, where groups could be most interested in "serving the needs of the youngest of the group", and being that facilitating factor for the youth. We know from past research that a large number of adult visitors to HMSC identify themselves as facilitators of their families' learning (Nickels. 2008). We also see a marked difference between Individual Youth and Multi-generational groups, which is further evidence that the presence of an adult facilitates more focused use by a youth. The difference seen between the two types of Individuals and Multi-generational groups could also be explained by the presence of social interaction in the Multi-generational group, which will be further discussed in Design Claim 3.

Finally Peer groups are the only group type that does not have Done as the most common first or total visit. They are also the group that spends the longest amount of time at the exhibit, potentially because they are not leaving as frequently as the other groups right after the Intro pages. The most common first visit is to Info, suggesting that Peers on the whole are interested in the background information presented in the Estuary and LOBO pages. The subsequent most common total visit after this first visit to Info, as well a first visit to Easy, is a total visit in Easy&Hard. Since Peers are spending the most amount of time at the exhibit, it can be inferred that they are most likely engaging in some of the activities presented in the exhibit. I would also propose that it is evidence of a shared use goal in interaction with the

exhibit. Shared goals are important to any group activity, and it is possible that this shared goal allows them to find the most appropriate level within the exhibit and engage with the activities there. Other groups appear to have slightly more difficulty in quickly finding the appropriate level for them to engage in since so many are leaving and spending shorter amounts of time.

Design Claim 3: Both cognitive tools and social groups are important at this exhibit; individuals have different use patterns than other group sizes or types

First visits

The difference in use by Individuals and other groups is initially seen in first visits. A first visit to Done is completed most frequently by Individuals (Fig 32) and least frequently by Peers and Multi-generational groups (Fig 33). This pattern is more or less maintained when Individuals are separated by age, with Done the most frequented zone by Individual Youth and the second most frequented zone by Individual Adults (Fig 33). Nonetheless, this pattern does not have a quantitative significant difference between all group types (Table 8, $\chi^2 = 1.761$, $p = 0.623$). Visiting Easy first is not significantly different between all group types ($\chi^2 = 4.698$, $p = 0.195$) or between Peer and Multi-generational groups ($\chi^2 = 0.085$, $p = 0.770$), but is different between Individual Youth and Individual Adults ($\chi^2 = 4.694$, $p = 0.30$). This indicates that all non-individual groups are visiting Easy first in a different manner whereas Individual Youth are visiting Easy first significantly less frequently than Individual Adults.

Table 8. Chi-square analysis of the first visits by group type.

	Individual Youth	Individual Adult	Peers	Multi-generational	X^2	p-value
Visited Intro Only					1.761	0.623
No	78.8%	72.7%	86.2%	80.4%		
Yes	21.2%	27.3%	13.8%	19.6%		
First Visit Easy[1,2]					4.698	0.195
No	90.9%	69.7%	79.3%	76.5%		
Yes	9.1%	30.3%	20.7%	23.5%		
First Visit Hard					.371	0.946
No	81.8%	75.8%	79.3%	78.4%		
Yes	18.2%	24.2%	20.7%	21.6%		
First Visit Info					2.916	0.405
No	84.8%	87.9%	72.4%	78.4%		
Yes	15.2%	12.1%	27.6%	21.6%		

[1] Individual Youth and Adults only: $X^2 = 4.694$, $p = 0.030$

[2] Peers and Multi-generational Groups only: $X^2 = 0.085$, $p = 0.770$

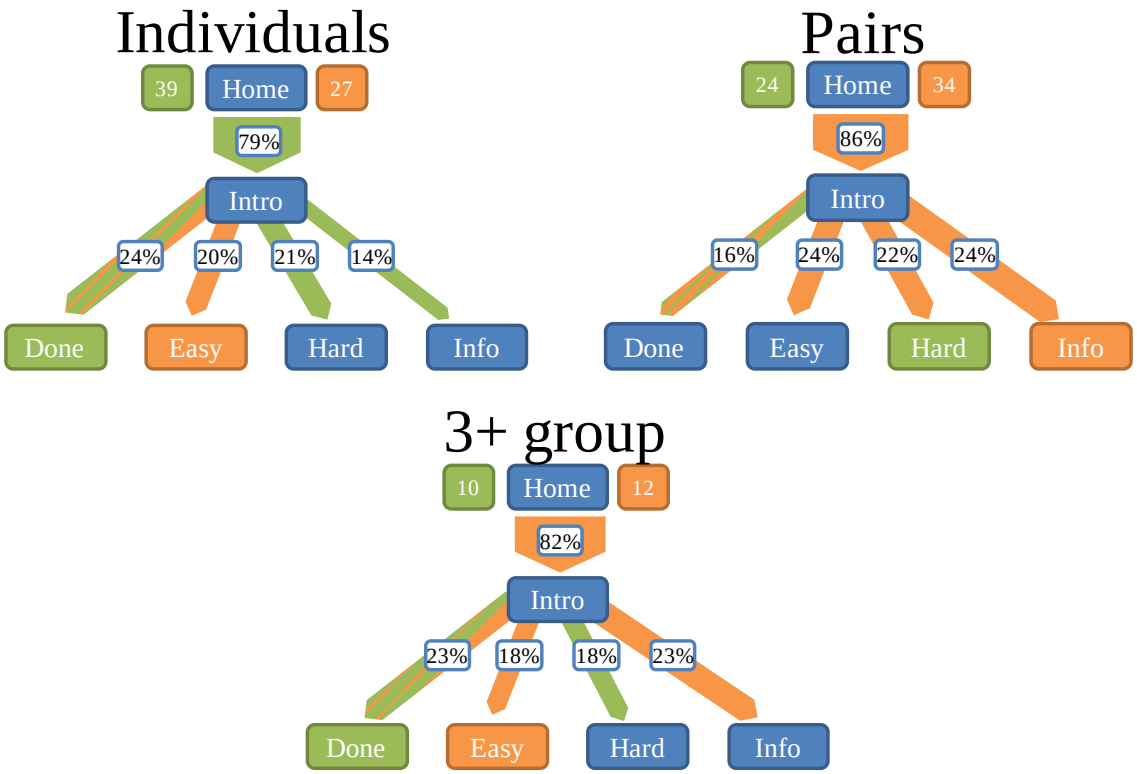


Figure 32. First visit paths for each group size. Green is the fall and orange is the winter. The numbers on either side of the Home box is the total number of visitors in that group type for fall (green) and winter (orange). The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path.

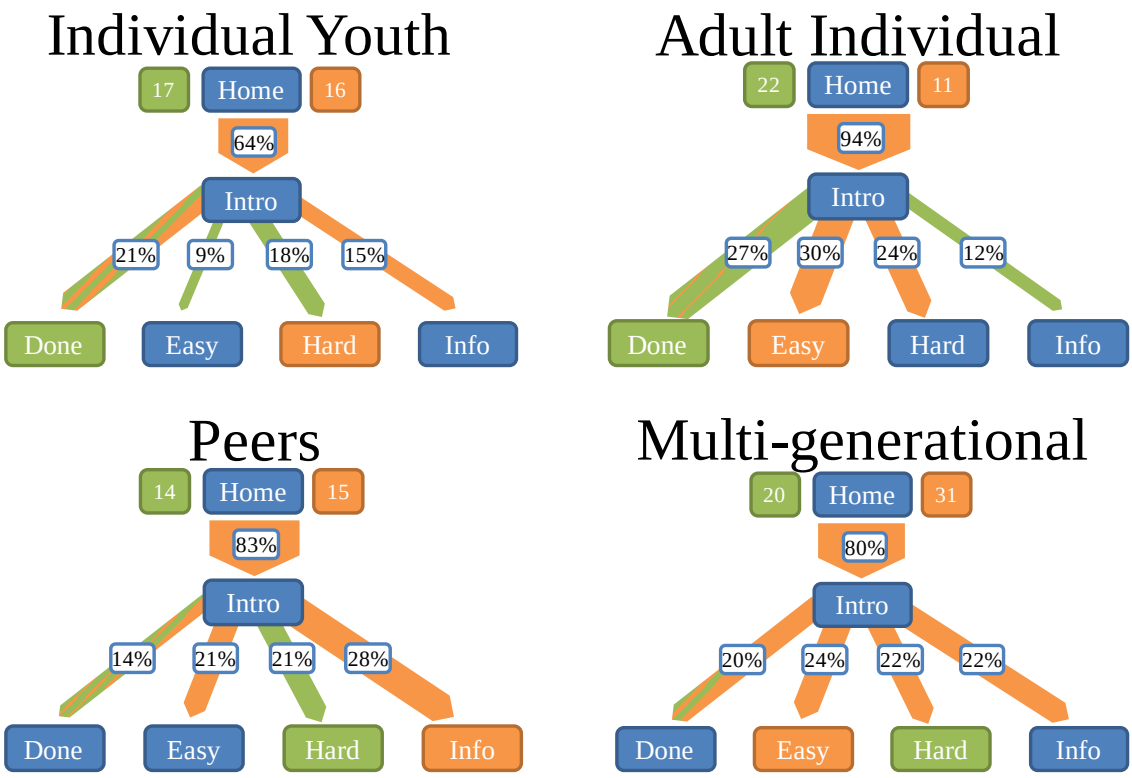


Figure 33. First visit paths for each group type. Green is the fall and orange is the winter. The numbers on either side of the Home box is the total number of visitors in that group type for fall (green) and winter (orange). The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path.

Total visits

Total visits tell a very similar story. The path-based total visits for Individual Adults and Multi-generational groups are the same as all combined visitors where the majority of groups stay in Easy Only or Hard Only after a first visit in that zone (Fig 34). Individual Youth and Peer groups, on the other hand, do not follow this pattern since only 33% of first visits to Easy stay in Easy Only for both group types. As might be expected based on the qualitative path-based analysis, the quantitative

destination-based total visit, or where a visitor ended up visiting regardless of the first visit, shows that there is a significant difference for visits to Easy Only between all group types (Table 9, $\chi^2 = 8.109$, $p = 0.044$). More specifically, we see that the path-based, qualitative difference between Individual Youth and Individual Adults is supported by a destination-based significant difference ($\chi^2 = 7.543$, $p = 0.006$), but there is a conflict between the results of the path-based and destination-based analysis between Peer and Multi-generational groups since there is no significant difference in the destination-based total visits ($\chi^2 = 0.081$, $p = 0.893$). This discrepancy for Peer groups can be explained by the visitors that visited Easy Only after visiting Info first; 30% of Peers (8 groups) visited Info first (Table 8) and 3 of these groups then visited Easy only, whereas only 15% of Individual Youth visited Info first (Table 8) with none visiting Easy Only afterwards. So even though the path-based visits look similar between Peers and Individual Youth, the destination-based analysis helps understand the full story of visitor use. Since Info is not included in the path-based analysis but is an important first visit for Peer groups, utilizing the destination-based total visits is necessary to build a comprehensive story.

Table 9. Chi-square analysis of destination-based total visits by group type.

		Individual Youth	Individual Adult	Peers	Multi-generational	X^2	p-value
Total Visit Not Learning Levels						2.361	0.501
	No	60.6%	69.7%	75.9%	74.5%		
	Yes	39.4%	30.3%	24.1%	25.5%		
Total Visit Easy Only[1,2]						8.109	0.044
	No	97.0%	72.7%	75.9%	74.5%		
	Yes	3.0%	27.3%	24.1%	25.5%		
Total Visit Hard Only						2.236	0.525
	No	84.8%	69.7%	75.9%	78.4%		
	Yes	15.2%	30.3%	24.1%	21.6%		
Total Visit Easy&Hard						3.634	0.304
	No	69.7%	87.9%	72.4%	78.4%		
	Yes	30.3%	12.1%	27.6%	21.6%		

[1] Individual Youth and Adults only: $X^2 = 7.543$, $p = 0.006$

[2] Peers and Multi-generational Groups only: $X^2 = 0.018$, $p = 0.893$

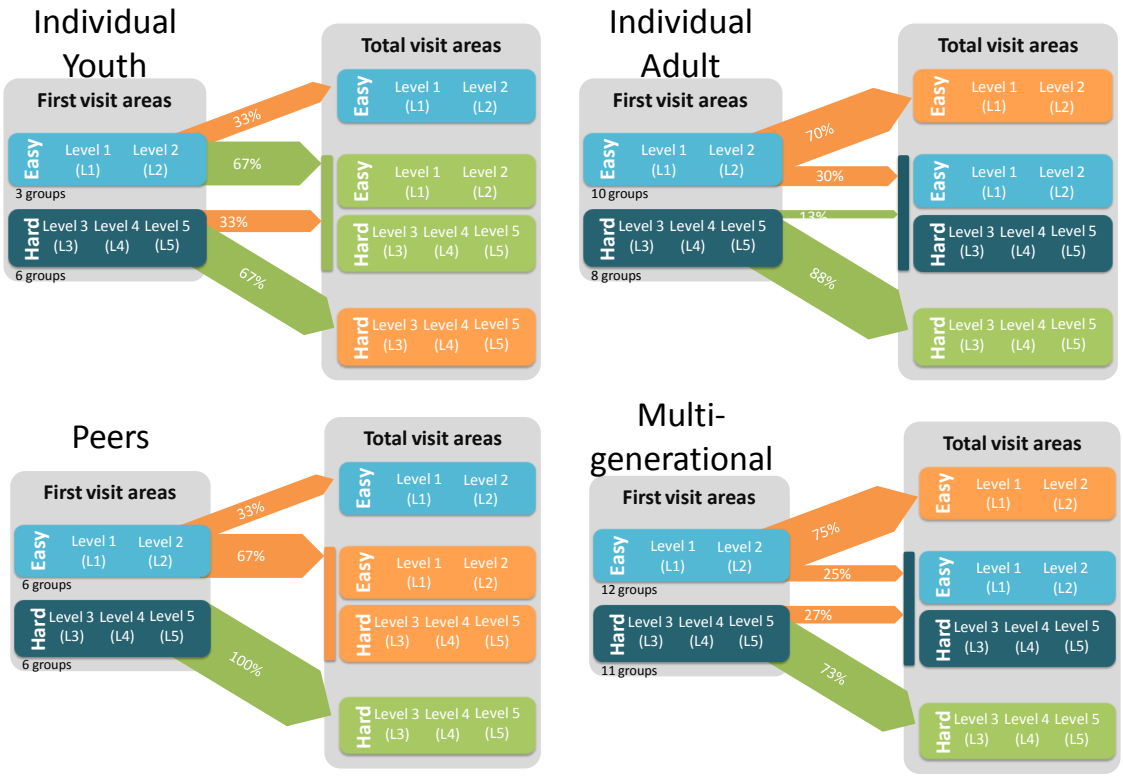


Figure 34. Path-based total visits for group types. Green is the fall and orange is the winter. The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path. The green total visit box indicates the most common visit zone in the fall and orange is the most common in the winter.

Influence of visit zone on the amount of time spent

Total time spent at the exhibit on the whole and also based on zones visited provides insight as to the differences between the group types. Here the general time trends are outlined for the different group types as well as for all combined visitors based on the first or total visit zone. Group types spend significantly different amounts of time at the exhibit (Table 10, $\chi^2 = 21.258$, $p = 0.002$), with Peer groups spending the most, Individual Adults spending a similar but slightly less amount of time than Multi-generational groups, and Individual Youth spending the least amount

Table 10. Chi-square analysis of the time spent at the exhibit by group type.

	Individual Youth	Individual Adult	Peers	Multi-generational	X^2	p-value
Under 1 min	63.6%	48.5%	27.6%	37.3%	21.258	0.002
1 to 4 min	24.2%	45.5%	31.0%	47.1%		
More than 4 min	12.1%	6.1%	41.4%	15.7%		

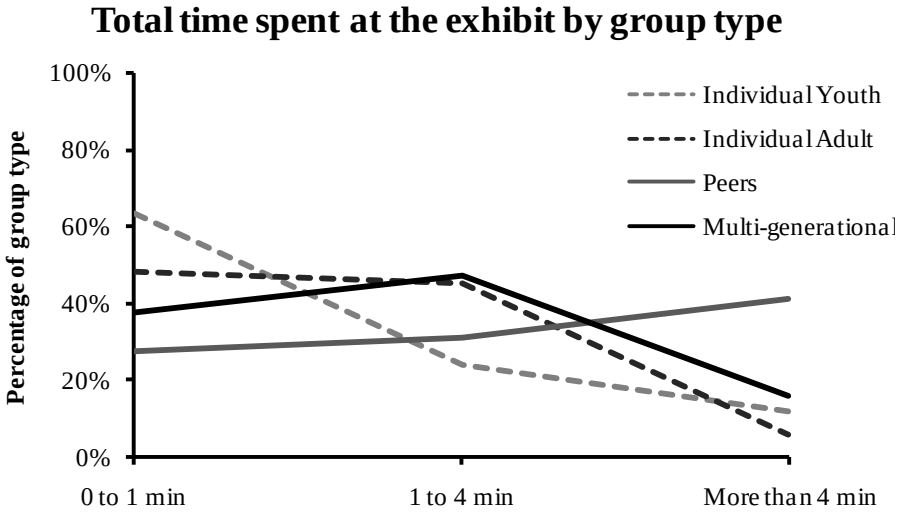


Figure 35. Total time spent at the exhibit by group type.

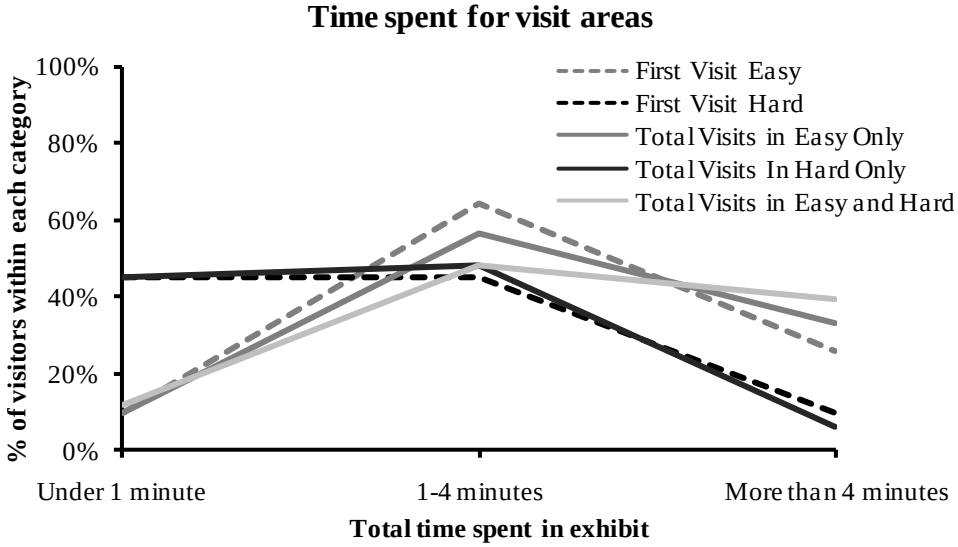


Figure 36. Time spent at the exhibit based on visit zones in the Learning Levels.

Table 11. Chi-square analysis of amount of time spent at the exhibit based on visit zones.

	No	Yes	X^2	p-value
First Visit Easy			18.911	0.000
Under 1 minute	53.0%	9.7%		
1-4 minutes	31.3%	64.5%		
More than 4 minutes	15.7%	25.8%		
First Visit Hard			1.952	0.377
Under 1 minute	43.5%	45.2%		
1-4 minutes	36.5%	45.2%		
More than 4 minutes	20.0%	9.7%		
Total Visit Easy Only			18.272	0.000
Under 1 minute	52.6%	10.0%		
1-4 minutes	33.6%	56.7%		
More than 4 minutes	13.8%	33.3%		
Total Visit Hard Only			4.47	0.107
Under 1 minute	43.4%	45.5%		
1-4 minutes	35.4%	48.5%		
More than 4 minutes	21.2%	6.1%		
Total Visit Easy&Hard			22.079	0.000
Under 1 minute	53.1%	12.1%		
1-4 minutes	35.4%	48.5%		
More than 4 minutes	11.5%	39.4%		

of time (Fig 35). We also see that visitors who visit Hard first ($\chi^2 = 1.952$, $p = 0.337$) or Hard Only ($\chi^2 = 4.470$, $p = 0.107$) spend the least amount of time at the exhibit out of all of the Learning Levels and that the visitor distribution between the three time categories for each zone is not significantly different from the groups that did not visit that zone (Table 11). Whereas the majority of Hard first or Hard Only visitors spend less than 4 minutes at the exhibit, the majority of Easy first, Easy Only, or Easy&Hard visitors spend more than 1 minute at the exhibit (Fig 36).

With the baseline time patterns outlined, the time patterns of the different group types based on first and total visit to Learning Level zones are now examined. A first visit to Easy engaged all Individual Youth and Individual Adults and the majority of Peer and Multi-generational groups to stay at the exhibit for longer than 1

minute (Fig 37). Individual Adults have the smallest percentage of groups spending more than 4 minutes, and since the same higher percentage of Individual Youth, Peer, and Multi-generational groups spend more than 4 minutes, this suggests that adding a youth to an Individual Adult, thus making a Multi-generational group, would increase the time spent by the Individual Adult (Fig 37). The similar shape pattern of the time spent for a first visit to Easy is seen for those that visit Easy Only (Fig 38) or Easy&Hard (Fig 39) in total, but with some small changes. Because the majority of Peer groups spend more than 4 minutes at the exhibit in both total visit zones, instead of adding a youth to an Individual Adult like in a first visit to Easy to increase time spent, adding a Peer to either Individual group type would increase the time spent. A first visit to Hard, however, results in very similar time patterns for Individual Adults, Peer and Multi-generational groups with the majority of groups spending less than 4 minutes at the exhibit and the majority of the Individual Youth spending less than 1 minute at the exhibit (Fig 40). Hard Only is the only total visit zone that groups spend a significantly different amount of time ($\chi^2 = 14.670$, $p = 0.023$) and results in all Individual Youth spending less than 1 minute and all Individual Adult and Multi-generational groups spending less than 4 minutes at the exhibit (Fig 41). Here, the need for an adult to facilitate using the exhibit is apparent since the addition of an adult to an Individual Youth, making a Multi-generational group, decreases the percent of groups spending less than 1 minute from 100% to less than 40%. The similarity between the Individual Adult and Multi-generational groups indicates, however, that adults may be dictating the length of stay at the exhibit, and if no other adults are present in the Multi-generational group, that adult may be acting more like an Individual Adult than like a Multi-generational unit. This is supported by the amount of time spent by Peer groups, where the addition of another adult to an Individual Adult, making a Peer group, increases the time spent dramatically.

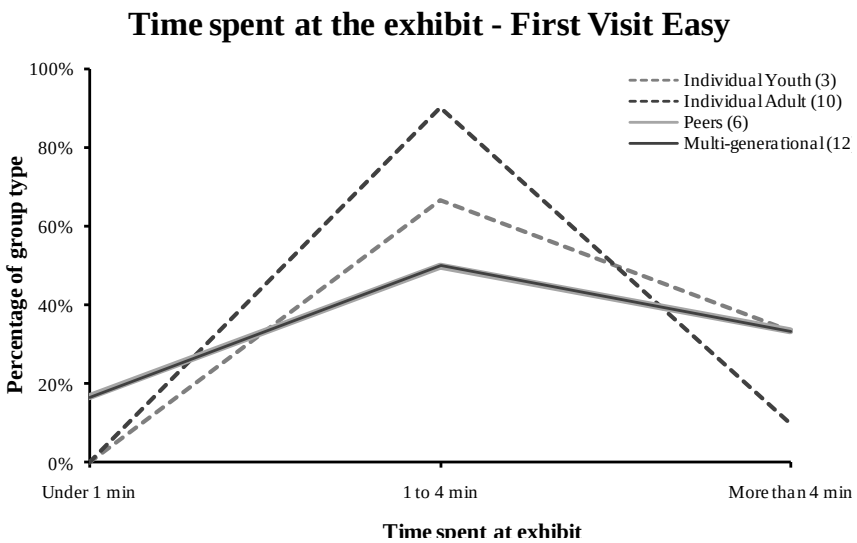


Figure 37. Total time spent at the exhibit by group types that visited Easy first. The number of groups in the group type is indicated in parentheses next to the type name.

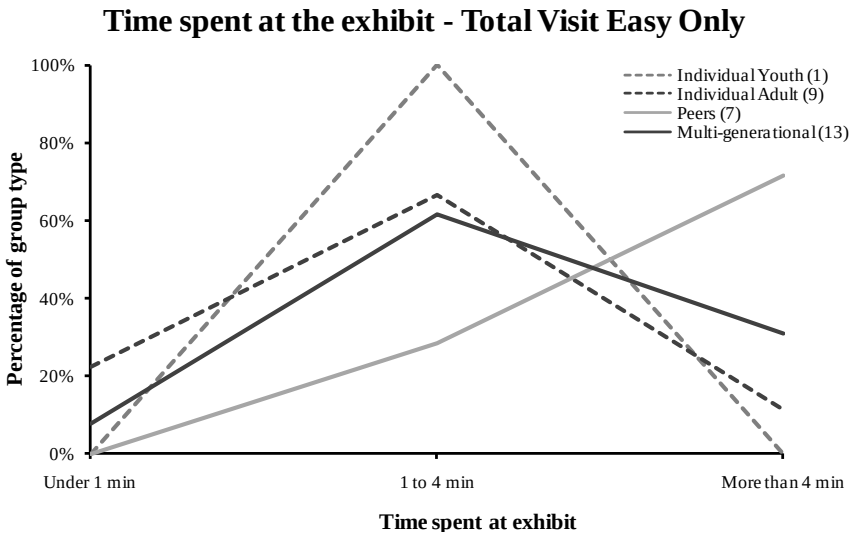


Figure 38. Total time spent at the exhibit by group types that visited Easy Only. The number of groups in the group type is indicated in parentheses next to the type name.

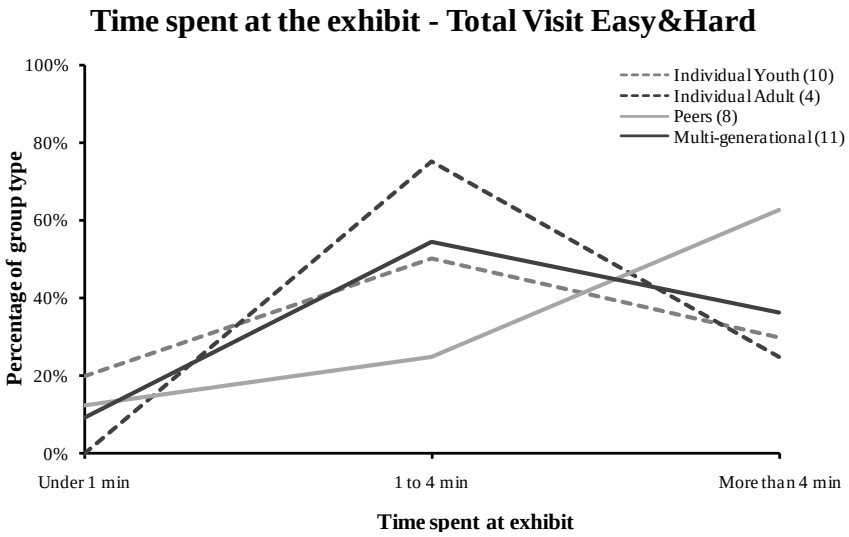


Figure 39. Total time spent at the exhibit by group types that visited Easy&Hard. The number of groups in the group type is indicated in parentheses next to the type name.

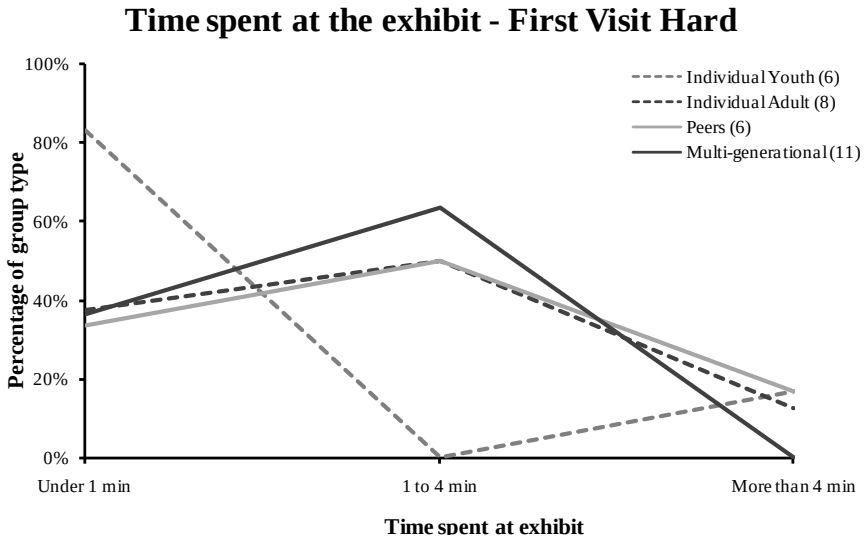


Figure 40. Total time spent at the exhibit by group types that visited Hard first. The number of groups in the group type is indicated in parentheses next to the type name.

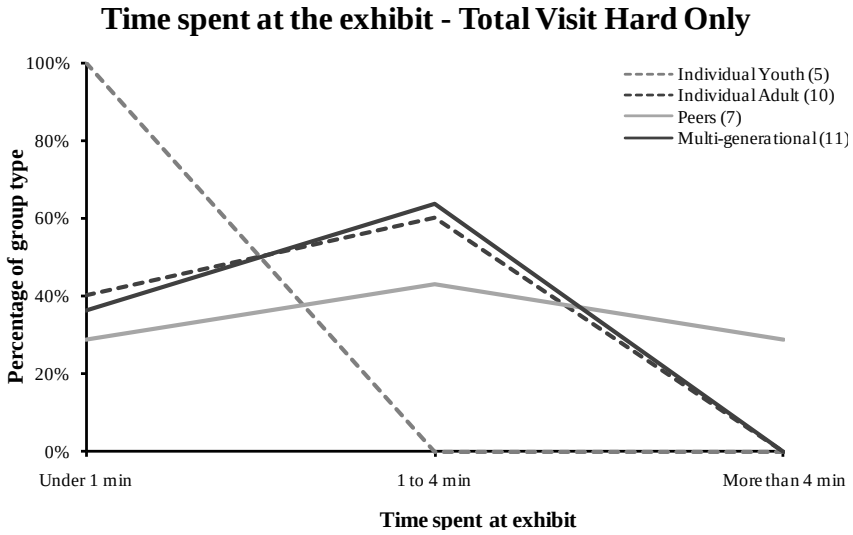


Figure 41. Total time spent at the exhibit by group types that visited Hard Only. The number of groups in the group type is indicated in parentheses next to the type name.

Synthesis

The differences in use seen between the two types of Individuals (adult and youth) and the two larger groups (Multi-generational and Peer) could stem from where they start their interaction with the exhibit. An initial explanation for these differences is that Done is the most frequented first visit zone by Individuals whether they are youth or adults. The total time these two groups are spending at the exhibit looks like the same distribution seen for first or total visits to Hard, where the assumption, based on other exhibit research that the majority of visitors spend the least amount of time, is upheld. This is cause for some investigation since the other two larger groups, Peers and Multi-generational groups, do not fit within this time assumption.

For Individual Youth, there are many potential factors that could be contributing to the observed exhibit use patterns. First we see that Individual Youth are the only group that doesn't have a relatively even distribution of visitors between the visit zones with Easy as the least visited zone (only 3 out of 33 youth went there first) but potentially the most appropriate place for a Youth to engage with the exhibit.

This could possibly indicate that there is a preference by Individual Youth to actually avoid the Easy levels, possibly because they perceive those levels to be less interesting; however, we see that the Easy levels have the largest amount of time spent at the exhibit for youths. Because youth are spending longer amounts of time in Easy than in Hard, there must be some other factors at play that explain why so few youths are visiting Easy. One possibility is that the presentation format of the information in the Intro pages is not appropriate for youths in understanding which level to choose on the second Intro page. Another possibility is that, especially for younger visitors who cannot read yet but are attracted to the computer and touch screen, the navigation button on the first Intro page is relatively in the same position as the buttons linked to the Hard levels on the second page. As a result, the youngest youth may be automatically touching those buttons without a direct goal. Either way, because of the small number visiting Easy, it can be deduced that changes made to the exhibit from V2.0 to V3.0 did not make a dramatic shift in use by this group. Further research must be done on this group to determine how to focus this group into the appropriate first visit in Easy, and if that is achieved, if the Learning Levels in Easy are in fact appropriate for their knowledge and skill set.

Individual Adults also have an interesting story. The path-based and destination-based total visits are fairly similar to those of Multi-generational or Peer groups, yet we see much different time patterns between Individual Adults and the other two groups. For a first visit to Easy or a total visit to Easy Only or Easy&Hard, adding either a youth or another adult to an Individual Adult to make a Multi-generational or Peer group will extend the time spent at the exhibit, whereas in Hard only adding another adult to make a Peer group would extend the amount of time spent at the exhibit. Solitary visitors are rarely studied and because of this are poorly understood, but these findings suggest that just having one other person at the exhibit can change the use patterns seen. These use patterns, which as an Individual are determined based on intrinsic, self-focused motivations, are shaped by social group dynamics and possibly intrinsic, other-focused motivations, like enhancing

relationship bonds or to scaffold learning and assist in focusing the use by a youth. Alone, adults do not have the tendency to stay at the exhibit as long as the multi-person groups, which suggests the importance of the social group interaction while engaging with an exhibit.

The longer engagement time by Peers and Multi-generational groups suggests that, as pointed out previously, the social group interaction is a necessary component to interacting with an exhibit in a way that promotes its use as a cognitive tool. These multi-person groups do not have any quantitative difference between their visit patterns at the exhibit, which shows that the type of social group is not important in determining where in the exhibit the group will visit. However, visit zones do seem to be a determining factor in the amount of time spent for the two different groups. Except a first visit to Easy where the same percentage of Peers and Multi-generational groups spent the same amounts of time, Peers always spent more time at the exhibit than Multi-generational groups. There are several possible explanations for this. First, the attention span of the youth in Multi-generational groups may be lower than most adults. Some of the adults observed in this study as well as anecdotal observations from evaluations of other exhibits suggests that this may not be the case (Rowe, pers.com. May 28, 2009), but some adults were observed to stay behind and continue interaction with the exhibit after the youth left. Also, the level of difficulty in the Hard levels could be a limiting factor in how much time families spend at the exhibit, especially with younger children who may only have a cursory knowledge, if any, about salinity. However, these groups are spending more time at the exhibit than Individuals potentially because adults can utilize the exhibit as a scaffolding tool for the youth in their group, but also because it gives the adult the chance to learn something themselves. It also potentially provides youth a chance to show off and demonstrate their knowledge and ability to their parents.

Peers, on the other hand, the majority of which were teens or adults, seem to have similar skills and knowledge that is appropriate for the exhibit and the exhibit fosters a shared experience within these groups. Perhaps the attention spans are longer

in these groups which is why they are spending more time than family groups, but the time patterns suggest that it is in fact the information in the Harder levels that are a major constraint in the Multi-generational groups. With no difference in percent of groups visiting any of the zones in total between Peers and Multi-generational groups, these group types have an equal chance to spend the same amount of time at the exhibit for a total visit in Hard only, but Peers are the only group type to spend more than 4 minutes in those levels. This suggests that the knowledge and skill levels that the older Peer groups possess along with the shared social interaction with at least one other peer is key to spending more time at the exhibit.

Design Claim 4: First visits and total visits influences time across group sizes and types

Building on the overall patterns of visits and time for each group size and type described in Design Claim 3, this claim expands upon the influence of visits zones on the amount of time spent at the exhibit by different types and sizes of groups.

Graph Interpretation

For this analysis, influence comparison was made between first visits to Easy and Hard, total visits to Easy Only and Hard Only, total visits to Easy&Hard and Hard Only, and total visits to Easy&Hard and Easy Only. The magnitude of influence is determined by subtracting the number of visitors in the visit zone listed second within target time category from the number of visitors in the visit zone listed first within the target time category (e.g., # of visitors that visited Hard first and stayed under 1 minute - # of visitors that visited Easy first and stayed under 1 minute = magnitude). A positive magnitude bar indicates there were more groups in the visit type listed first, and a negative magnitude bar indicates there were more groups in the visit type listed second. An equivalence ratio was also calculated, in order to indicate the relative

equivalence of the two groups compared, in a similar manner of the magnitude calculation, except that the groups were divided instead of subtracted. An equivalence ratio of 1, coupled with the lack of a magnitude bar, indicates that the two groups being compared are equal in number, and lesser equivalence is indicated as the ratio moves farther away from 1 and approaches 0 for negative magnitudes or higher integers for positive magnitudes. A ratio of ø indicates that there is no ratio, or coupled with a lack of a magnitude bar, that there are no groups in that category.

Individuals

The influence of an Individual's first visit is very strong for both the under 1 minute and 1-4 minute time categories, as indicated by the large magnitudes and ratios (Fig 42). Under 1minute has a -8 magnitude with no ratio, meaning that no groups in this time category visited Easy first, only hard, and that 8 Individuals visited hard first and spent less than 1 minute. The 1-4 minute category has a positive magnitude of 7 with a ratio of 2.75, so for every 2.75 Individuals that visited Easy first and stayed for 1-4 minutes, only 1 Individual who visited Hard first stayed for the same amount of time. Essentially, when Individuals visit Hard first, they are more likely to leave within the first minute of their interaction, and when Individuals visit Easy first, they are more likely to stay between 1-4 minutes. Lastly, the 4+ minute category was equivalent with a 1 ratio, indicating that first visit zones were not influential in the amount of time spent.

A similar pattern to the time spent at the exhibit based on first visits was seen in total visit zones as well. For the comparison of total visits in Easy Only to total visits in Hard Only (Fig 43), and total visits in Easy&Hard to total visits in Hard Only (Fig44), the under 1 minute categories for both had a-7 magnitude with a small equivalent ratio, and the 1-4 minute categories had a positive magnitude of 1 for Easy and 2 for Easy&Hard. The large magnitude for the under 1 minute category is similar to the magnitude in the first visit, indicating that total visits to Hard only have the

same influence on time spent as first visits to Hard; however, there is a small equivalence ratio, .22 for both Easy and Easy&Hard, which means that for every 2 visits to Easy only there were 9 visits to Hard only, which unlike the first visits since some groups less than 1 minute groups did visit Easy as well as Hard. For the 1-4 minute category, both the magnitudes and ratios were less than those for the first visits, indicating a still that visiting Easy or Easy&Hard has a greater influence on spending more than 1 minute at the exhibit, though the ratios are close to 1 which shows that the influence of visiting Hard only is more equivalent to visiting Easy only or in conjunction of visiting Hard. This indicates that for the 1-4 minute category, a total visit to one zone is not as influential on time spent at it was for the first visits. Lastly, the total visits did have a strong influence on the 4+ minute categories; there were positive magnitude bars and no ratios for either comparison, meaning that no individuals that visited Hard only stayed for more than 4 minutes.

The last total visit comparison is between Easy&Hard and Easy only (Fig 45). For under 1 minute, there was an equivalent ratio of 1, 1-4 minutes had a magnitude of 1 with a 1.14 ratio, so almost equal influence of either total visit zone on time, and 4+ minute magnitude of 3 and a ratio of 4, meaning that individuals that visited both Easy&Hard levels spent more time at the exhibit than those that visited Easy only.

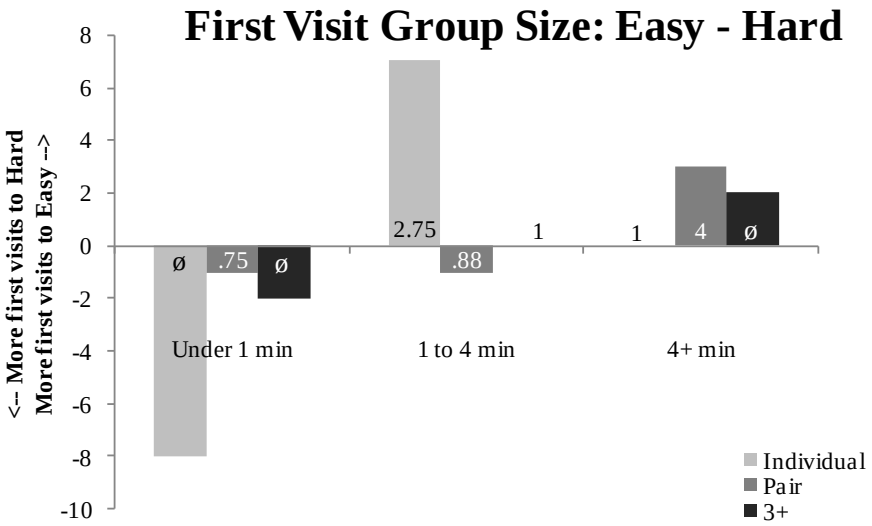


Figure 42. The relative influence of first visits to Easy or Hard on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio.

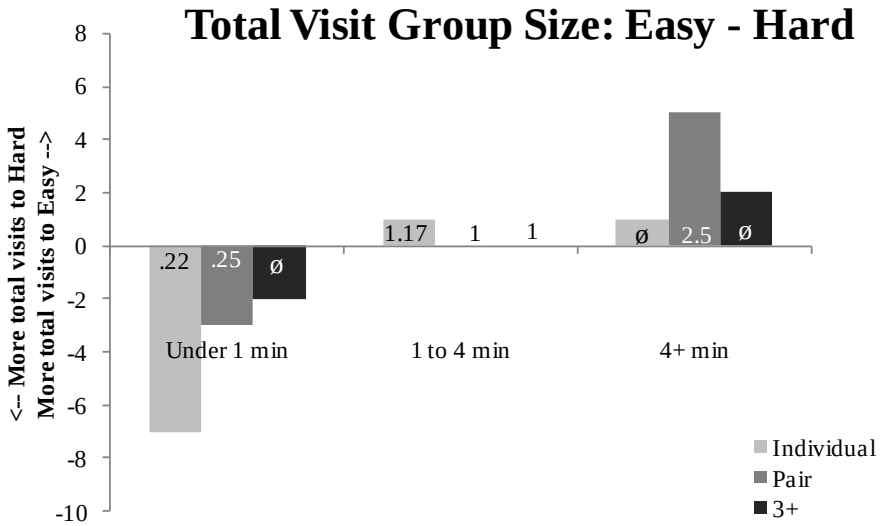


Figure 43. The relative influence of total visits to Easy or Hard on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio.

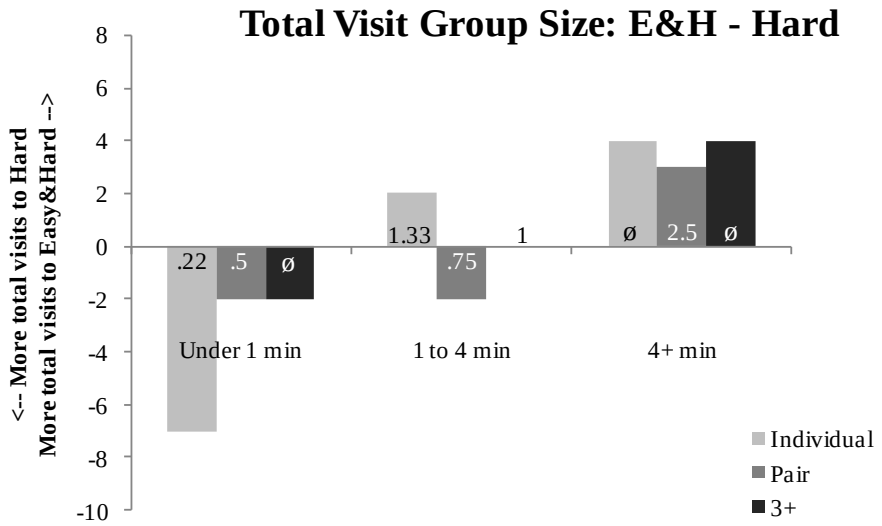


Figure 44. The relative influence of total visits to Easy&Hard or Hard on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio

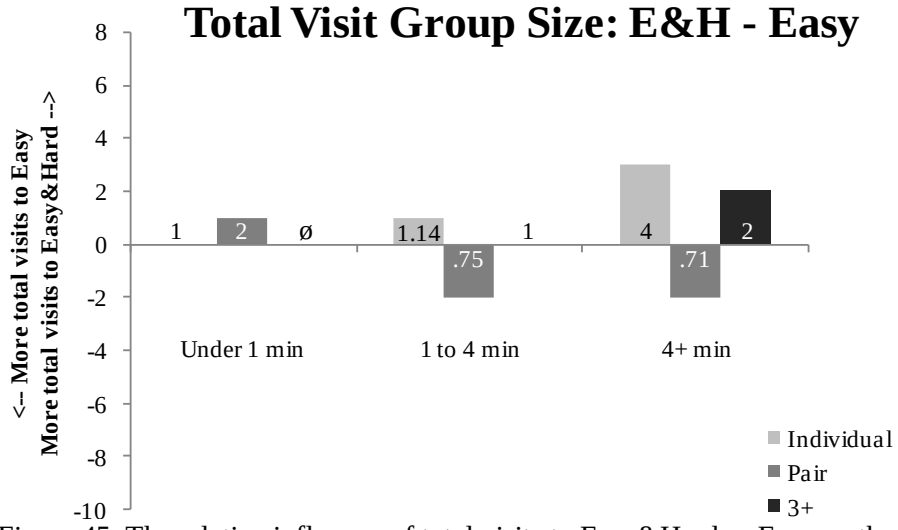


Figure 45. The relative influence of total visits to Easy&Hard or Easy on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio

Pairs

In examining the influence on where Pairs visited on the amount of time spent at the exhibit, the three figures comparing to Hard only has a negative or equal magnitude for all visitors that spent less than 4 minutes at the exhibit, but large positive magnitudes and ratios for the 4+minute categories. For first visits, under 1 minute and 1-4 minutes has a -1 magnitude with a .75 ratio for under 1 minute and .88 ratio for 1-4 minutes (Fig 42). The ratios are close to 1, which means that even though more Pairs visited Hard first than Easy, the first visit zone does not have a strong influence on the amount of time under 4 minutes that they stay. For total visits between Easy Only and Hard Only, under 1 minute again had a negative magnitude but with a small ratio, indicating that for every 1 Pair that visited Easy Only and left there were 4 Pairs that visited Hard Only and left (Fig 43). This also means, when compared to first visits, that a total visit to Hard Only is a stronger influence on leaving the exhibit in less than 1 minute than a first visit to Hard is. In the 1-4 minute category, the groups were equally visiting Easy Only and Hard Only, indicating that there is little to no influence based on total visits to Easy Only or Hard Only. In the 4+ minute category, there was a magnitude of 5 and a ratio of 2.5, indicating that a total visit to Easy Only has a stronger influence on Pairs to stay longer than 4 minutes than a total visit to Hard Only.

The comparison between a total visit in Easy&Hard and Hard Only features a similar pattern to the comparison between Easy Only and Hard Only (Fig 44). Under 1 minute has a negative magnitude with a moderate equivalent ratio of .5, 1-4 minutes has a ratio of .75, and 4+ minutes has a magnitude of 3 and a 2.5 ratio. The influence of visiting Hard Only is greater in both under 4 minute categories, but the ratio in the 1-4 minute category indicates more equivalence with those that visit Easy&Hard.

Again, the influence on visiting Easy in conjunction with Hard has a stonger influence for Pairs to stay more than four minutes than just visiting Hard alone.

Finally, the comparison between total visits to Easy&Hard and Easy Only does not fit the expected trend of an increasing influence of Easy&Hard as time increases (Fig 45). The influence of visiting Easy&Hard is greatest over visiting Easy Only in the under 1 minute category; the magnitude is 1 with a ratio of 2. For the Pairs that stayed for more than 1 minute, the magnitude is the same for both categories (2) with similar ratios that are close to 1, .75 for 1-4 minutes and .71 for 4+ minutes. Even though the influence of visiting Easy Only or Hard in conjunction with Easy is almost equivalent, visiting Easy Only has more of an influence on Pairs to stay at the exhibit longer than 1 minute.

Groups of 3 or more

In determining influence of visiting Easy or Hard first, the groups that stayed for less than 1 minute all had a -2 magnitude with no ratio, indicating that no groups that visited Easy first only stayed for less than 1 minute, and for the 4+ minute category there was a magnitude of 2 with no ratio, indicating that no groups that visited Hard first stayed for more than 4 minutes (Fig 42). In the 1-4 minute category, there is a -1 magnitude bar, indicating a greater influence of visiting Hard first, but the .88 ratio shows that the number of groups visiting Easy or Hard first in the category are almost equivalent. The comparison of time spent at the exhibit for total visits to Easy Only or Hard Only (Fig 43) and total visits to Easy&Hard or Hard Only (Fig 44) are almost exactly the same as the first visit, with only 1-4 minutes being exactly equal with a ratio of 1 for both total visit comparisons and the magnitude bar increasing to 4 for the total visits to Easy&Hard. Finally, in comparing the influence of time spent at the exhibit by total visits to Easy&Hard or Easy Only, no groups were in the under 1 minute category, the 1-4 minutes category had an equal ratio of 1, and 4+ minutes had a 2 magnitude with a 2 ratio (Fig 45). This indicates that visiting Easy Only or

Easy&Hard influences groups of 3 or more to spend more than 1 minute at the exhibit and have an equal influence on groups these groups to spend 1-4 minutes. We also see that visiting Hard in conjunction with Easy will increase the amount of time groups of 3 or more spend above 4 minutes.

Individual Youth

Following the same trend as all the combined individuals, visiting Hard first or Only greatly influences the amount of time spent at the exhibit. For the first visit comparison between Easy and Hard, there is a -5 magnitude bar with no ratio for under 1 minute and a magnitude of 2 bar with no ratio for the 1-4 minute category (Fig 46). This means that no youth that visited Easy first stayed for less than one minute, and no groups that visited Hard first spent between 1 to 4 minutes. The 4+ minute category has an equivalent ratio of 1, meaning that there is no strong influence of one first visit zone over another. Total visits between Easy Only and Hard Only have a very similar pattern; under 1 minute has a -5 magnitude and no ratio, 1-4 minutes has a 1 magnitude with no ratio, and 4+ minutes has no magnitude or ratio, which means that no youth that visited Easy Only or Hard Only spent more than 4 minutes at the exhibit (Fig 47). In the time comparison of total visits to Easy&Hard and Hard Only, the magnitude for under 1 minute was -3 with a .4 ratio, whereas the two categories above 1 minute had positive magnitudes, 5 for 1-4 minutes and 3 for 4+ minutes, with no ratio, so no youth visited Hard Only and spent more than 1 minute at the exhibit (Fig 48). In comparing total visits to Easy&Hard and Easy Only, all of the magnitude bars were positive with no ratios in the under 1 minute or 4+ minute categories, and a magnitude of 4 and ratio of 5 in the 1-4 minute category (Fig 49). This shows that youths, except for the one in the 1-4 minute category, did not visit Easy Only, and that visiting Easy&Hard does not influence how long they stay at the exhibit.

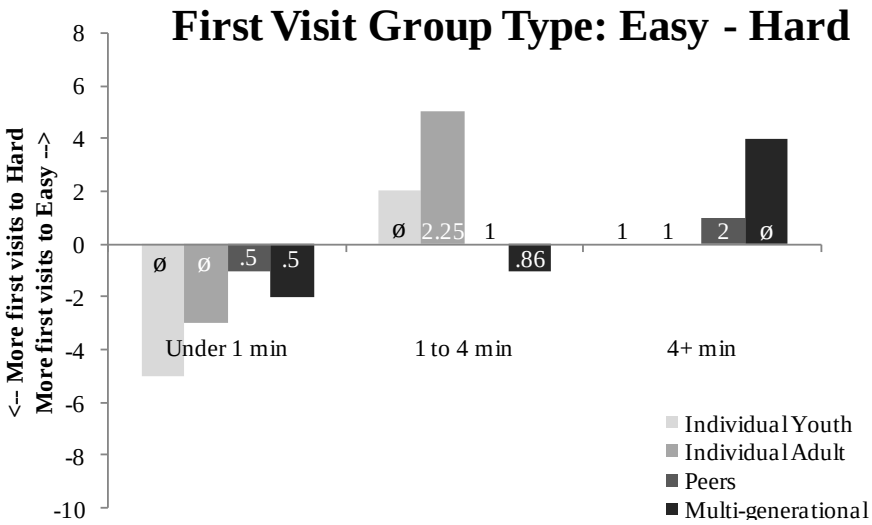


Figure 46. The relative influence of first visits to Easy or Hard on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio

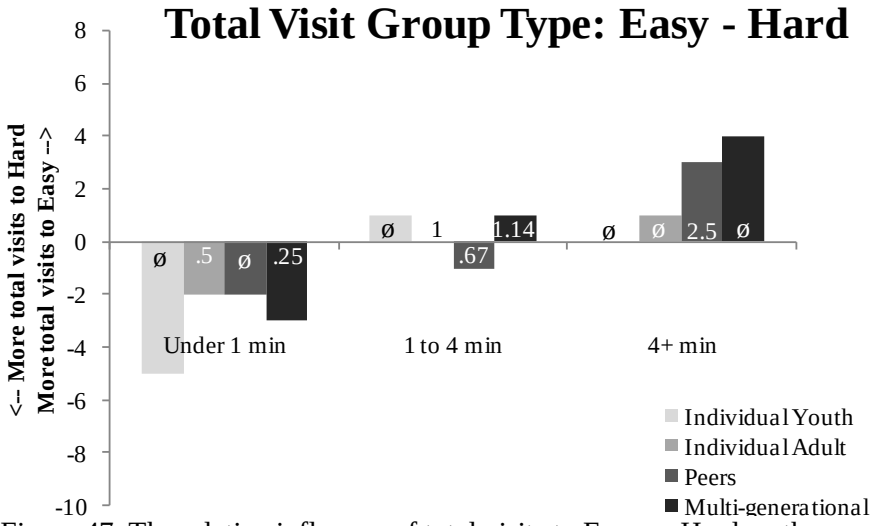


Figure 47. The relative influence of total visits to Easy or Hard on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio

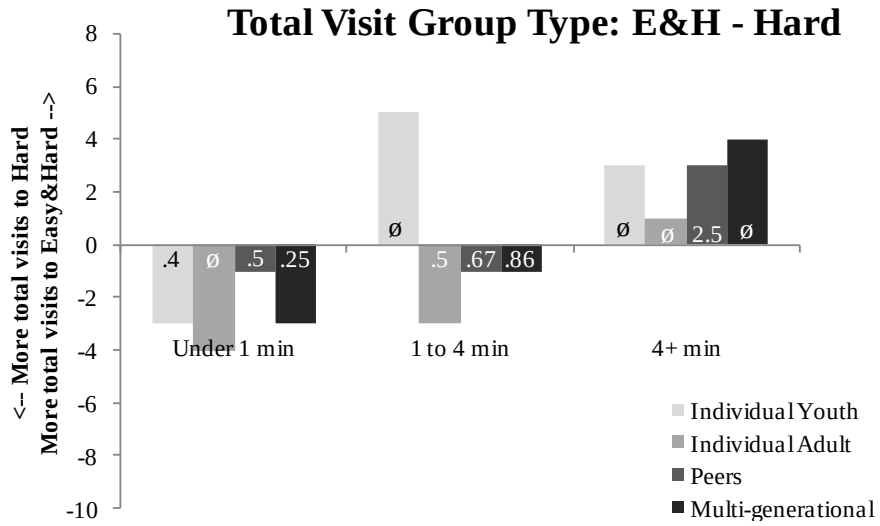


Figure 48. The relative influence of total visits to Easy&Hard or Hard on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio

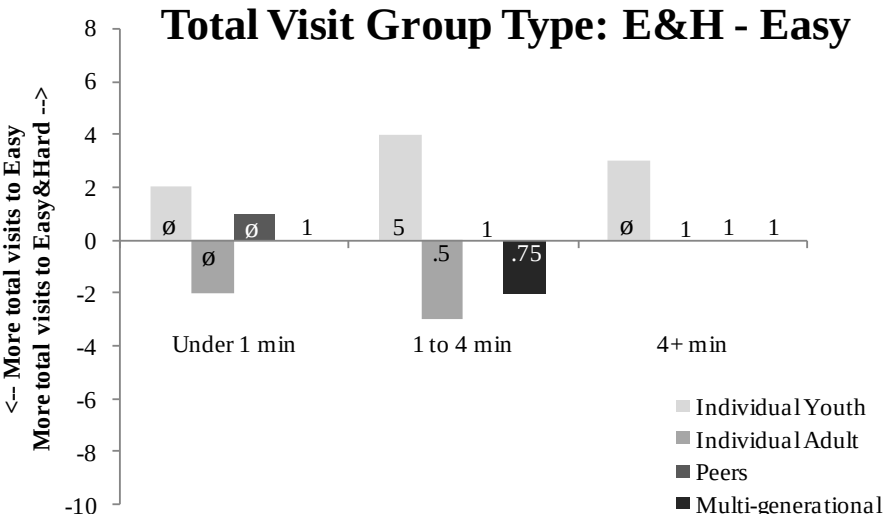


Figure 49. The relative influence of total visits to Easy&Hard or Easy on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal and ø indicating no ratio

Individual Adult

When comparing zones visiting with total time spent at the exhibit, adult individuals have similar patterns to all combined individuals. For the first visit to Easy or Hard comparison, the under 1 minute category had a -3 magnitude with no ratio, 1-4 minutes had a 5 magnitude with a 2.25 ratio, and 4+ minutes had a equivalent ratio of 1 (Fig 46). Like the combined individuals, this means that no adults that visited Easy first stayed for less than 1 minute, visiting Easy first has a greater influence on adults to stay between 1 and 4 minutes, and for those that spent four minutes or more, where they visited first was of equal influence. Comparing total visits between Easy Only and Hard Only, under 1 minute had a negative magnitude, 1-4 minutes had a equal ratio of 1, and 4+ minutes had a positive magnitude with no ratio (Fig 47). For the under 1 minute category, the ratio is .5, a moderate equivalence since for every one adult visiting Easy Only there are two visiting Hard Only, but still indicating that a total visit in Hard Only will influence more adults to spend under 1 minute at the exhibit. The influence of visiting Easy Only or Hard Only is equivalent in the 1-4 minute category, and no adults who visited Hard Only spent more than 4 minutes at the exhibit.

The comparison of total visits to Easy&Hard and Hard Only has a similar pattern in the under 1 minute and over 4 minute categories (Fig 48). The -4 magnitude and no ratio in the under 1minute category indicates that no adults that visited Easy&Hard stayed for under 1 minute, and the 1 magnitude and no ratio in the 4+ minute category indicates the opposite, that no adults that visited Hard Only spent more than 4 minutes at the exhibit. In the 1-4 minute category, there is a -3 magnitude, indicating that visiting Hard Only has a greater influence on adults in this time category, which is supported by the moderate equivalent ratio of .5. In comparing total visits to Easy&Hard and Easy Only, visiting Easy Only has a greater influence on adults in the under 1 minute and 1-4 minute categories, and visiting

Easy&Hard or Easy Only has an equivalent influence in the 4+minute category (Fig 49). For under 1 minute, there is a -2 magnitude with no ratio, and 1-4 minutes has a -3 magnitude with a .5 ratio, indicating that visiting Easy Only has a greater influence on staying at the exhibit for under 4 minutes than visiting Easy&Hard, but the influence of visiting Easy&Hard is more equivalent in the 1-4 minute category. Visiting either Easy&Hard or Easy Only has equivalent influence on individual adults to stay more than 4 minutes.

Peers

Looking at first visit influences on time, in general the influence of either first visit zones are equivalent. In the under 1 minute category, there is a -1 magnitude and .5 ratio, but for the two categories above 1 minute there is a ratio of 1, where there is no first visit zone that is a stronger influence than the other on the peer groups to stay that amount of time (Fig 46). In the under 1 minute category, the trend seen is expected and shared between all group types and sizes that visiting Hard first has a greater influence to leave the exhibit than visiting Easy first. In comparing total visits of Easy Only and Hard Only, a different pattern arises (Fig 47). Under 1 minute has a -2 magnitude with no ratio, 1-4 minutes has a -1 magnitude with a .67 ratio, and 4+ minutes has a magnitude of 3 and a 2.5 ratio. Visiting Hard Only has a stronger influence on peers than visiting Easy Only to stay at the exhibit for less than 4 minutes, but the two zones are closer in influence equivalence in the 1-4 minute category than the under 1 minute category, were visiting Easy Only has no influence. In the 4+ minute category, visiting Easy Only has a strong influence, as indicated by the magnitude and large ratio. The comparison between total visits to Easy&Hard and Hard Only is exactly the same as the comparison between Easy Only and Hard Only except for the under 1 minute category (Fig 48); the magnitude here is -1 with a .5 ratio, so visiting Easy&Hard has a slight influence on peer groups to spend less than 1 minute at the exhibit whereas visiting Easy Only didn't. This is supported by the

comparison between total visits to Easy&Hard and Easy Only, where under 1 minute there is a magnitude of 1 with no ratio, so no influence of visiting Easy Only to spend less than 1 minute at the exhibit (Fig 49); however, the other two time categories above 1 minute have a ratio of 1, so there is no difference in influence on the amount of time peer groups spend at the exhibit between visiting Easy Only or visiting Easy&Hard.

Multi-generational groups

In examining the influence of first visit zones on the amount of time spent, visiting Hard first had a greater influence to spend less than four minutes at the exhibit and no influence on spending more than four minutes at the exhibit (Fig 46). Under 1 minute has a -2 magnitude with a .5 ratio and 1-4 minutes has a -1 magnitude with a .86 ratio; 4+ minutes has a magnitude of 4 with no ratio. The influence of Easy Only or Hard Only as total visits is very similar for the under 1 minute and 4+ minute categories, with the under 1 minute magnitude of -3 and ratio of .25 and the 4+ magnitude of 4 and no ratio (Fig 47); however, in 1-4 minutes, there is a magnitude of 1 and a ratio of 1.14, indicating that visiting Easy Only has a greater influence on spending 1-4 minutes at the exhibit, but this influence is close to equivalent with visiting Hard Only. Comparing total visits to Easy&Hard to Hard Only has, again, a similar pattern (Fig 48). Visiting Hard Only has a greater influence on groups spending less than 4 minutes at the exhibit, with a -3 magnitude and .25 ratio in under 1 minute and -1 magnitude and .86 ratio in the 1-4 minute category; however, the influence of Hard Only on groups to spend 1-4 minutes is marginal, as indicated by the ratio close to 1. In the 4+ minute category, the 4 magnitude and no ratio shows again that visiting Hard Only has no influence on groups to spend more than 4 minutes at the exhibit. Finally, the comparison of visiting Easy&Hard or Easy Only shows that those zones have equal influence on groups to spend under 1 minute or more than four minutes (Fig 49). In the 1-4 minute category, the -2 magnitude indicates a stronger

influence by visiting Easy Only, but the .75 ratio that is close to 1 shows an almost equivalent influence by visiting Easy&Hard.

Synthesis

We see that there is an overall pattern of visit influence seen in all group sizes and group types. Looking at the groups in both type and size categories that spent less than 1 minute at the exhibit, there is a consistent trend that these groups are being influenced by their first or total visit to Hard Only. We might expect that visitors would need a longer amount of time to complete the activities in the Hard levels since they encourage exploration and more open-ended discussion. Based on these results alone, there are two possible explanations why this expectation was not met, either groups are completing the tasks much quicker than we expected, or they are not engaging in the tasks as we anticipated or at all. The observations of how visitors were interacting with these levels shows that the majority of groups did not engage in the activities at all for both V2.0 and V3.0, the former of which had included some major changes in attempts to change this visitor use pattern. Some groups did engage in the activities as anticipated or accessed the internet as instructed but then went elsewhere on the web thus not engaging in the anticipated activity, both of which typically extended the amount of time spent at the exhibit. Even though the strength of this visit to Hard levels varies between groups since other groups did visit Easy or Easy&Hard and spend less than 1 minute at the exhibit, the pattern that groups who spent less than 1 minute at the exhibit did so because of their visit in Hard levels is very strong. This then raises the question of why visitors are only spending a limited amount of time at these levels, is it due to the knowledge of the visitors that is required for these advanced activities, or is it due to the activities themselves that do not align with visitor interests? This answer cannot be provided by this study, but is worth further research in order to best understand how to present these types of datasets to the general public.

We also see a fairly consistent trend in groups that stay at the exhibit longer than 4 minutes are influenced by their visits to Easy or Easy&Hard. The only groups that did not fit this trend was the Individuals, where there was an equal influence of a first visit to Hard and first visit to Easy on spending more than 4 minutes at the exhibit. Starting this discussion with Easy levels, no amount of time was necessarily anticipated for these activities; however, we did anticipate that there would be a general limit to the amount of time spent since the activities have a definite termination point. For the groups that spent more than 4 minutes at the exhibit, visiting the Easy levels had a very strong influence on the amount of time that they spent than the Hard levels, suggesting, as mentioned before, that these levels are either within the groups' knowledge range or interest level. With the literature showing that the majority of visitors spend 30 to 60 seconds at an exhibit, the fact that groups are staying at the exhibit while engaged in these activities for much longer than that is a good indication that we have presented them with activities that align with one or both of these criteria. For the visitors that visit both Easy&Hard levels, the influence of the Hard levels on visitors to spend less than 1 minute at the exhibit suggests that even though both zones were visited, the Easy levels are probably lengthening the time spent more so than the Hard levels. In examining the influence of visiting Easy Only against visiting Easy&Hard together, there is no strong pattern that can be described across all groups, and both of these zones show equal influence in many of the time categories in both group types and group sizes. Therefore no concrete conclusions can be made about the difference in influence between Easy Only and Easy&Hard, but it is evident that both of these zones have a strong influence on groups who stayed for longer than 4 minutes.

Finally, the one to four minute category is examined. For Individuals, both Youth and Adults, visiting Easy first has a much stronger influence on these groups to stay for this amount of time. However, where Individual Youths maintain this pattern in visits to Easy Only, a visit to Easy Only or Hard Only is an equivalent influence on Individual Adults in this time category. With no Individual Youth staying at the

exhibit for longer than 4 minutes if they visit Easy Only or Hard Only, this suggests that these youth have a time limit for focused use. Looking at their patterns in the Easy&Hard comparison, except for one instance visiting Easy&Hard has a stronger influence on all the time categories than a visit to Easy Only or Hard Only, suggesting that there is no true pattern of use for this group. When we do see this group in the appropriate zone, Easy, they are spending more time than those that visited Hard with a time limit of between 1 and 4 minutes. Individual Adults on the other hand, do not show such a pattern in the 1 to 4 minute category, possibly because they have a broad range of knowledge and interests that creates difficulty in making generalizations for this group. One generalization that can be made about all the groups except for Individual Youth is that this 1 to 4 minute category seems to be a transition period between the Hard influenced under 1 minute groups to the Easy or Easy&Hard more than 4 minute groups. The influences on this time category have a broad range and many equivalencies arise, especially between Easy Only and Hard Only for all the group sizes, so more research is needed to get a better view at what exactly is influencing the groups to stay at the exhibit for this long. These influences may be only directly related to the activities in the exhibit, but it is also suspected that other factors external to the exhibit are also a strong influence.

Conclusions

A visit to Hard first or Hard Only has a strong influence on staying at the exhibit for under 1 minute. A visit to Easy first, Easy Only, and Easy&Hard have a stronger influence than Hard on staying for more than 4 minutes, which is fairly consistence across all group types and sizes, except for any type of Individual. The influence of visits in 1-4 minutes is variable and depends on the group structure, but, excepting Individuals, there is generally an equal influence of visit zones in this time category. It seems that the 1 to 4 minute category is a transition zone and more research is needed to understand the factors influencing groups in this time category.

CHAPTER 5: LEARNING-BASED FINDINGS

Learning Claim 1: The exhibit successfully addressed general misconceptions about salinity

Misconceptions are alternate views or explanations for any type of issue, and are especially prevalent in science. Misconceptions develop from a variety of sources (a person's social group, the media, teachers, etc), and are generally resistant to change unless a person is confronted with contradicting information. Misconceptions then change if learners experience a restructuring of their cognitive schema to incorporate this new information (Osborne, 1985). Unintentionally, this exhibit addresses three misconceptions included in the "110 Misconceptions About the Ocean" list (Feller, 2007):

- There are no real seasons in the ocean
- Oceans have the same salinity everywhere
- Salty oceans are not linked to land's freshwater cycle

The overall design concept for the exhibit was to explain that there are seasons in the estuary and what the differences between these seasons are. The salinity poster is entitled *Rhythms of the Seasons: Can we tell the season both above and below the water*, and Level 2 and parts of Level 3 in the computer exhibit were dedicated to explaining how the seasons in the Bay are defined and how the salinity changes because of meteorological and ocean-based factors that differ between summer and winter. These concepts are innately linked to the other two misconceptions, since the graphs and activities in the exhibit all highlight how salinity changes in the estuary, and the majority of the explanation for this deviation from the average ocean salinity and the change in salinity levels over time is due to rainfall and freshwater discharge from the river. The effectiveness of the exhibit in addressing these misconceptions is reflected by the new information users picked up from the exhibit as identified in interviews.

Table 12. Coded responses to the question "did you learn anything from the exhibit?"

	Child	Teen	Adult	Multi-gen	Total
Learned					
Salinity related	1	1	5	5	12
Rainfall related	0	0	4	4	8
Vocabulary	0	1	1	1	3
Nothing	0	1	1	0	2

Answers from the interviews that had to do with these three misconceptions were coded into four categories: salinity related; rainfall related; vocabulary; or nothing. The greatest number of comments was related to salinity in some way, and included comments about what the salinity in the bay or ocean is, as well as comments about the daily, monthly, or seasonal changes of salinity in the Bay (Table 12). Youths who were part of multi-generational groups learned that the amount of salt in the ocean and in the Bay changes over the year; one youth learned that the salinity in the Bay is highest during the month of his birthday, September. Learning about the salinity is not restricted to just kids; one individual adult said that she learned about the ebb and flow of salinity on the daily cycle, and other adults in a peer group said that they knew what fresh and salt water were, but didn't know they mixed in coastal waters and that the salinity changes throughout the year.

Another topic that visitors learned about was related to rainfall. Comments in this category include learning that the Oregon coast has a rainy season, that rain is actually such a significant factor for both residents and the environment, that there is a link between rain and river discharge, and that there are changes in the Bay's salinity because of the rain. Three adults from out-of-state were shocked either by the fact that it rained so much in Oregon, that there is an identifiable rainy season, or that the rainy season was in the winter. Adults from Colorado and Ohio were surprised by how much it rains on the coast, and the visitor from Colorado was surprised to learn how much of an influence the rain has on the salinity. In particular for this visitor, the

exhibit addressed a misconception based on her experience: she noted that in general it doesn't rain much in Denver, where she lives, and based on that knowledge, she would not have considered rain to be as influential as it appeared in the data. Another adult visitor grew up in Virginia Beach, where the rain storms occur during the summer, and this experience gave him some trouble in answering the questions in the exhibit. Multi-generational groups also mentioned how they learned about the relationship between rainfall and river discharge, and one adult asked the youth in his group "Didn't you learn that rain anti-correlates to salinity?" in response to answer the "What did you learn?" question.

Conclusions

The information visitors report gaining during their interaction helps us understand the information that visitors are focusing on and what some common types of information learned by visitors are as well as what misconceptions and experiences visitors might bring to making sense out of the exhibit The success of the presentation methods in Levels 1 and 2 are reflected in the comments of the visitors that they learned about the salinity of the ocean and the bay and how rainfall is an important determinant of salinity in the bay. Now that we know that these techniques are effective for salinity, they can be applied to other types of water quality variables with hopefully similar results.

Learning Claim 2: Patterns of speech are better explained by group type than by group size

The indicator of learning for this thesis is the talk complexity, or how many types of talk a group engages in. The complexity of talk for Pairs, Groups of 3 or more, Peers, and Multi-generational groups will be examined to determine if signs of

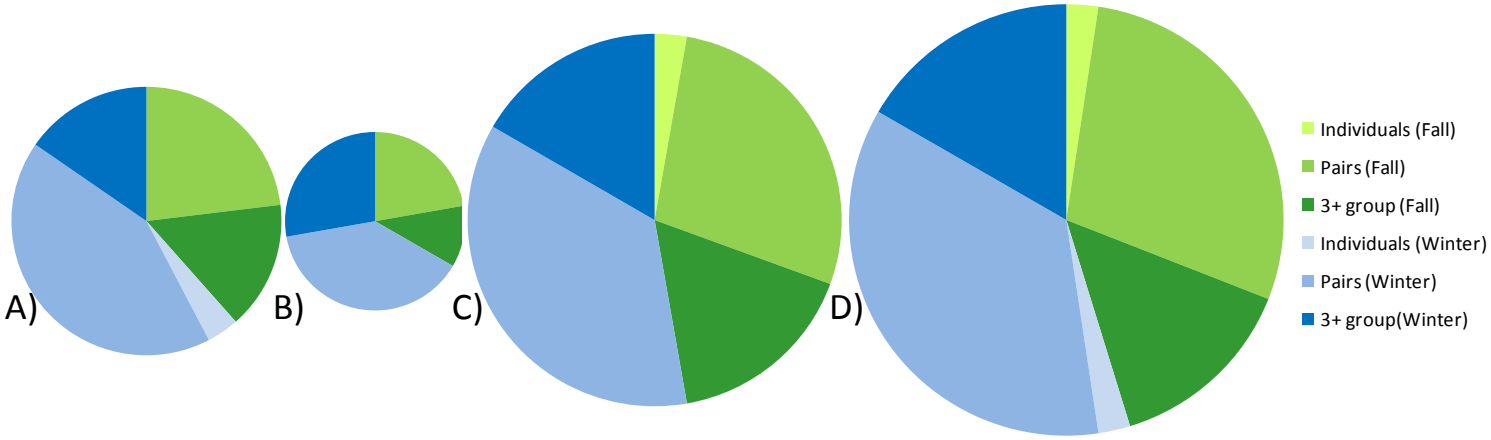


Figure 50.The representation of each group size category within each type of talk. The size of the circle is proportional to the percent of non-individual groups (80 groups total) that engaged in that type of talk. A) Read out-loud (31%) B) Ask a question (23%) C) Make a statement (44%) D) Any type of talk (50%).

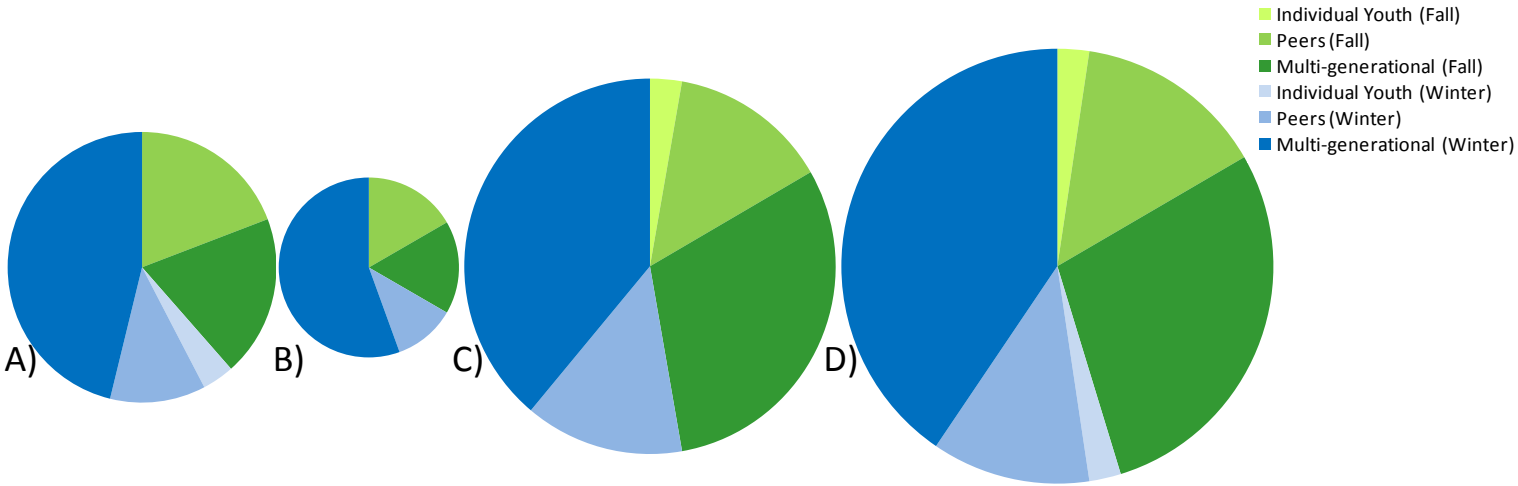


Figure 51. The representation of each group type category within each type of talk. The size of the circle is proportional to the percent of non-individual groups (80 groups total) that engaged in that type of talk. A) Read out-loud (31%) B) Ask a question (23%) C) Make a statement (44%) D) Any type of talk (50%).

learning were exhibited during use of the exhibit. Discussion here includes reasons behind whether talk is better described by a group's size or social structure.

Talk analyzed by group size

Out of the three different types of group size, Pairs talked the most. In each of the four types of talk pairs represented between 22% and 29% of the talk in the fall and 36% to 42% in the winter (Fig 50). Examining more closely the percent of Pairs that engaged in talk, the largest percentage in both evaluation rounds made a statement and the smallest percentage asked a question (Fig 52). The percentage of Pairs that read out-loud or asked a question was greatest in the winter, a trend among all visitors, but the percentage of pairs that made a statement or engaged in at least one type of talk was greater in the fall. In looking at talk complexity for Pairs, both the fall and winter fit the expected overall trend of a decrease in 2 types with an increase in 3 types of talking (Fig 52). 1 type of talking had the greatest decrease from fall to winter, and the groups in no type of talking was the only complexity type that did not meet the expected fall to winter change seen in all visitors.

Groups of 3 or more have slightly different talk patterns than the patterns of Pair groups. Even though Groups of 3 or more did not represent the majority of the talk in either of the evaluation rounds (Fig 50), a greater percentage of these larger groups engaged in talk than did Pairs with over half of Groups of 3 or more engaging in at least one type of talk (Fig 53). Similar to Pairs, the most frequently used talk type in either evaluation round was making a statement. In the fall the least used type of talk was asking a question, which is similar to Pairs, but in the winter the least used type of talk was reading out-loud. When comparing fall and winter percentages to see if the expected increase in percentage occurred, the only type of talk that fit the expectation was in asking a question. Also, the percentage of any type of talk is almost the same for fall and winter, indicating there is almost no change in the number of groups that engage in at least one type of talk. Looking at the talk complexity of

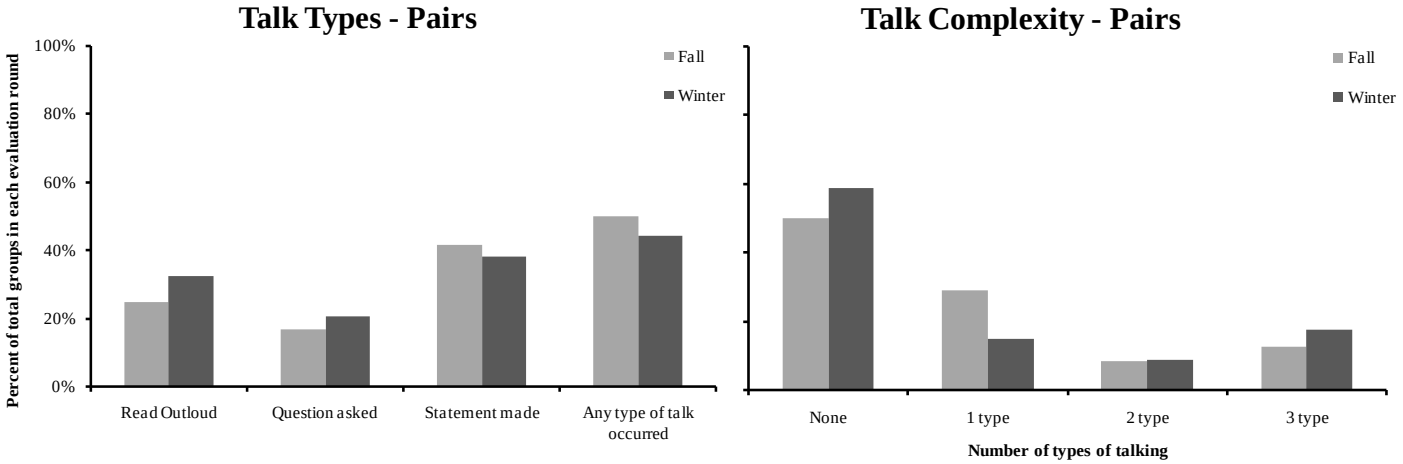


Figure 52. The talk types and talk complexity of Pair groups in the fall (n=24) and winter (n=34).

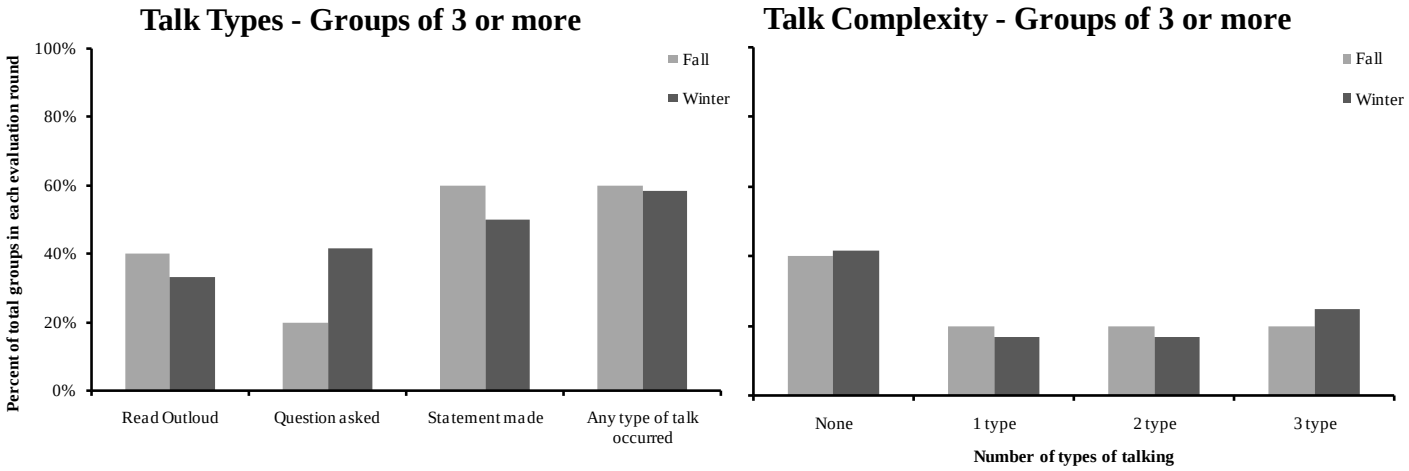


Figure 53. The talk types and talk complexity of Groups of 3 or more in the fall (n=10) and winter (n=12).

Groups of 3 or more, neither fall or winter groups completely fit the expected trend exhibited by all visitors (Fig 53). During the fall, visitors equally engaged in 1, 2, or 3 types of talk, whereas during the winter equal numbers of visitors engaged in 1 or 2 types of talk, with the greatest percentage during the winter engaging in 3 types of talk. Only in 1 and 3 types of talk does the expected change happen between fall and winter. At the same time there is a slight decrease in those that engage in 2 types of talk, because there is an increase in 3 types of talk. The lack of a clear pattern seen here in the types of talk is reminiscent of the lack of a clear pattern seen in visits in Design Claim 2- maybe there are too many people in the group to characterize them with the same categories as the smaller sized groups. It is true that the complexity of interaction rises exponentially with group size as the number of open channels of communication rises.

Talk analyzed by group types

Peers talked less than Multi-generational groups (Fig 51). For Peers most frequent type of talk is making a statement (Fig 54). All the percentages decreased from fall to winter, which conflicts with the pattern seen above for all visitors, with the smallest change in making a statement and the largest change in reading out-loud. In the winter, the percentage for making a statement is the same as any type of talk, indicating that all Peer groups that talked in the winter made a statement. For talk complexity, groups in the fall fit the expected trend of a decrease in 2 types of talk and an increase in 3 types, but no such change is seen in the winter. In the fall, the greatest percentage of groups engaged in 3 types of talk (Fig 54). In the winter, 1 and 3 types of talk was the lowest percentage seen in any of the groups (7%), and 2 types of talk was the highest percentage in the winter for Peers. However, just looking at 1 and 2 types of talk, the shift to more complex talk from fall to winter was seen since 1 type decreased and 2 types increased from fall to winter. The interesting part of this pattern is the large decrease in 3 types of talk from fall to winter since Peer groups, out of the

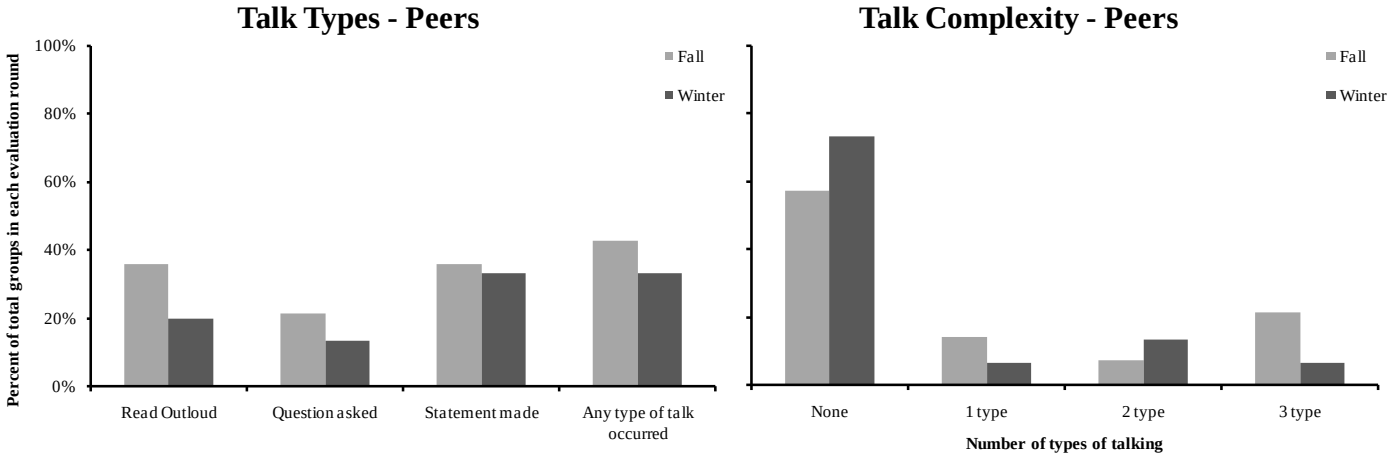


Figure 54. The talk types and talk complexity of Peer groups in the fall (n=14) and winter (n=15).

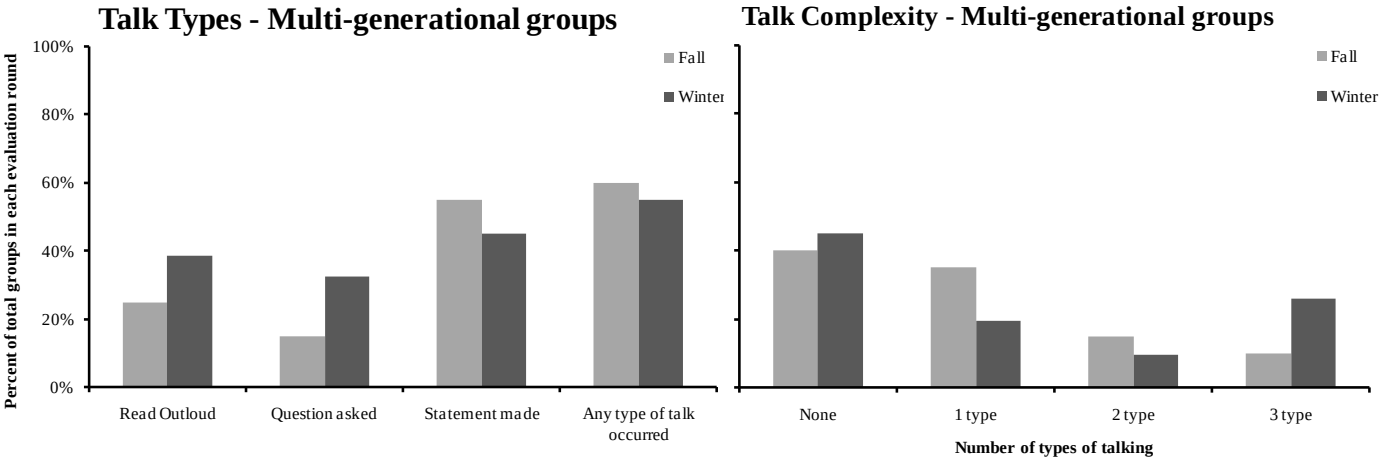


Figure 55. The talk types and talk complexity of Peer groups in the fall (n=20) and winter (n=31).

other group sizes and types, are the only group to show a decrease in 3 types of talking from fall to winter, and are the only group to have an increase in 2 types of talking that is greater than one percentage point.

Multi-generational groups show some very interesting talk patterns. Of all group types, they represented the majority of the talk that occurred in both evaluation rounds; the winter Multi-generational groups actually represent around half of the total talk (Fig 51). Looking specifically at the percent of Multi-generational groups, over half of groups engaged in talk, with making a statement the most frequently used type of talk in both evaluation rounds (Fig 55). In the fall, the percent of groups who made a statement was much larger than the percentages of those that read out-loud or asked a question, but in the winter the percent of groups that read or asked a question increased. At the same time making a statement slightly decreased making the three types of talk closer to being equally used. For all groups, having a question based interaction with a youth, either the adult or youth asking the question, was significantly different between evaluation rounds ($\chi^2 = 4.818$, $p = 0.028$), with 3% of groups the fall and 12% of groups in the winter. The large increase in reading and asking a question is similar to the pattern seen in all visitors, but in contrast making a statement and any type of talk decreased. For talk complexity, winter fit the expected trend where fall did not (Fig 55). During the fall, the largest percentage of groups engaged in 1 type of talk and there is a decreasing trend of groups from no talking to 3 types of talk, which is different than the trend seen in all visitors where there is an increase from 2 to 3 types of talk. In the winter, the greatest percentage of groups engaged in three types of talk, and the shift to a more complex pattern of talk is seen since 1 type of talk decreases from fall to winter and 3 types of talk greatly increase from fall to winter.

Synthesis

Based on observations of talk, there are a few patterns that stand out about how talk is used. Reading text from the slides out-loud, seemed to have several different motivations. Some adult peer pairs were observed reading the text out-loud, presumably to share the experience with their partner at the same time. They then used what they read as a springboard to start a discussion of how to start answering the question posed. Adults in multi-generational groups used reading out-loud in several different ways: as a hook to get the youth in their group interested in the exhibit; as a way to engage the youth in their group who were not of reading age; as a tool to get the youth in their group to read out-loud themselves (a type of literacy activity very common in science museums). Adults in Multi-generational groups used questions in a similar way, to scaffold a youth's experience and understanding of the information (refer to Groups C, D in the Introduction section to Chapter 4). Youth asked adults in turn to clarify what they were reading (Group B), to get the adult's opinion, or to confirm if they got the answer correct. Peers, however, either in a Peer only group or adult peers that are part of a Multi-generational group, used questions not to start a discussion or to scaffold the information but for clarification of what was being asked by the exhibit (Group E) or as a test to see if the others in the group knew what they did (Group A). To start a discussion, Peers were more likely to make a statement about how they perceived the information (Group 1). Multi-generational groups may have been scaffolding youth by "walking them through" thought processes that the adults had already accomplished internally (Group 4), or, in combination with reading from the slide, to start a youth's interaction (Groups 3, 5).

Applying these qualitative observations to the quantitative observations, we see the same trends. The percent of peer groups that engaged in making a statement barely changed from fall to winter, indicating that this type of talk is important to Peer groups. An inference further evidenced by the winter groups, where all the groups who talked made a statement. Since Peers used questions for clarification, the decrease in questions asked, even though it goes against the overall pattern seen in all visitors, can be seen as a result of fewer points of confusion in V3.0 of the exhibit.

Therefore, where a decrease in questions in Multi-generational groups would be alarming as it would indicate less talk directed toward scaffolding youth's participation, a decrease in Peer questions appears to be a welcome sign. This is coupled with the apparent decrease in Peer talk complexity (the large decrease in 3 types of talking from fall to winter). If how to use the exhibit is clear or intuitive, Peers would have less need to ask a question to clarify information. They would thus need or use 2 types of talking, making a statement or reading out-loud. An increase in 2 types of talk was seen, and coupled with the decrease in 1 type of talk indicates an increase in talk complexity for Peer groups: more of them are talking about the content of the exhibit rather than how it works. Out of all the groups, this is the only one where an overall decrease in talking complexity is a good sign.

Multi-generational groups, as explained above, use talk differently than Peer groups. Unlike Peers, Multi-generational groups increased in their usage of reading out-loud and significantly increased the rate of asking questions from fall to winter, which coupled together are a sign of increased scaffolding. Making a statement decreased, but as mentioned before this made the percent of groups engaged with either of these three types of talk more equal, suggesting that all three are useful tools of learning in an Multi-generational group. Borun et al. (1998) found that, in fact, the use of all of these types of talk together is an indicator that learning was occurring. Applied to this data, we can infer that more groups in the winter engaged in talk that is indicative of learning than those in the fall. The shift in talk complexity is most dramatic in Multi-generational groups, with 1 type of talk the most frequent in the fall and 3 types of talk the most frequent in the winter.

The patterns described here for Peer and Multi-generational groups were easy to discern and interpret, which is not as true for group size. As a categorization, group type relies on definite social roles that can be described without looking at any data. Group size, however, does not carry much information about what the expected interaction between group members is. We see that Groups of 3 or more have a greater percentage of groups talking than Pairs, which could just be a function of there

being more people in a larger group and therefore a higher probability of at least one person to say something in the group. However, we do see that Pairs represent a greater percentage of the talk that occurred. This could also be a function of the fact that there were 58 Pairs observed and only 22 Groups of 3 or more. Regardless, describing patterns of talk based on group size leaves several unanswered important questions of the cause, if any, of why these patterns are seen. For example, what would cause two people using the exhibit to engage in talk, or what would cause an increase in asking questions in a larger group? The latter can be explained by, again, referring back to group type patterns since most of the larger groups are Multi-generational (Fig 56), which explains why there was a large increase in questions asked from fall to winter. However, the former is more difficult to attempt to answer since Pairs are almost equally divided between Peer and Multi-generational groups and because the patterns of talk are so different, the pattern seen in Pairs could potentially be classified as virtually meaningless.

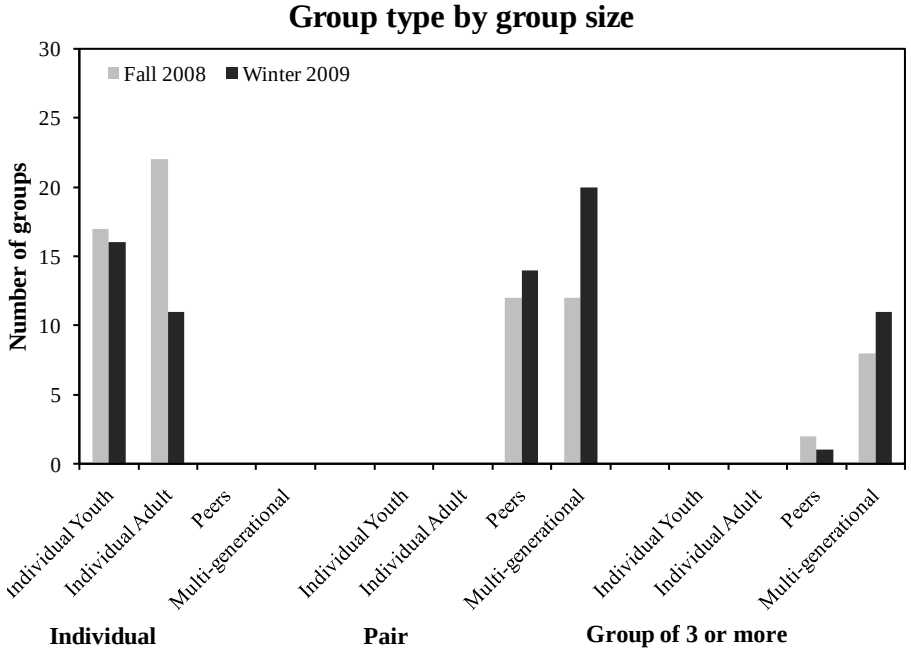


Figure 56. The percentage of groups in each group type based on the group size.

Conclusions

Learning in Multi-generational groups is shown by engaging in all three types of talking: reading out-loud, asking questions, and making statements. We saw that more Multi-generational groups engaged in learning indicating talk in the winter than during the fall, indicating that changes made in the exhibit to make V3.0 supported more learning opportunities. For Peer groups, using three types of talk as a learning indicator may not be as appropriate; if the information in the exhibit is clear, Peers show the need to ask questions and therefore using two types of talk may be an indicator of learning. More research should be done to determine if this is true as an addition to Borun's work of family learning. Lastly, we found that group size alone is not sufficient in interpreting talk patterns.

Learning Claim 3: First visit to Easy resulted in more complex and longer interaction than a first visit to hard

This claim is built on several parts and includes analysis of all three types of use: visits, total time spent, and talk that occurred. First the necessary elements from each of these use types will be presented. This will be followed by a discussion of the differences of use between those who visit Easy first and those who visit Hard first.

Visits and Time

The first method to determine if first visits influence use is to examine the amount of time spent, or put differently, does the first impression matter? Out of the four first visit zones, the time distribution of the groups that visited Hard first or Intro only have an overall decreasing trend as time at the exhibit increases, similar to the

standard time trend seen in all visitors (Fig 57). A first visit to Easy or Info exhibits a more normal curve distribution (Fig 58). Groups who visited Intro only, where 93% of visitors spent less than 1 minute, had a significantly different time distribution than those who visited one of the other zones first (Table 13, $\chi^2 = 37.621$, $p < 0.001$). Of those who visited Easy first, 65% spent 1-4 min at the exhibit, and 26% spent more than 4 minutes, which differs from the decreasing trend seen in all other groups

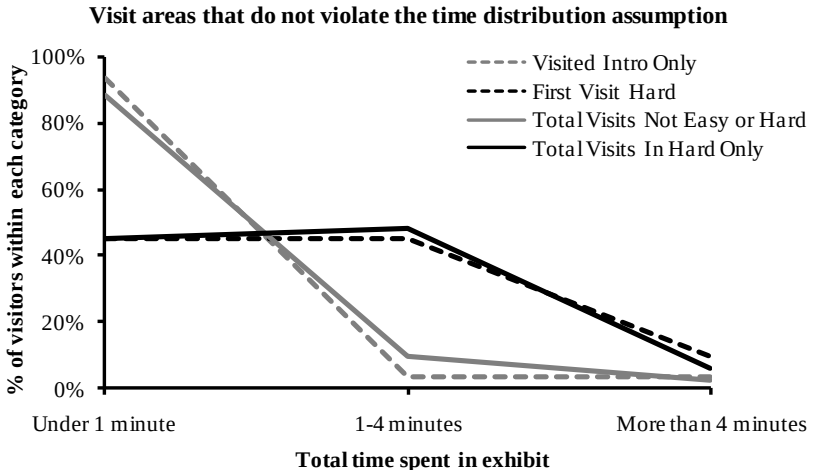


Figure 57. Visit zones in the exhibit that resulted in a large percentage of visitors spending lower amounts of time at the exhibit.

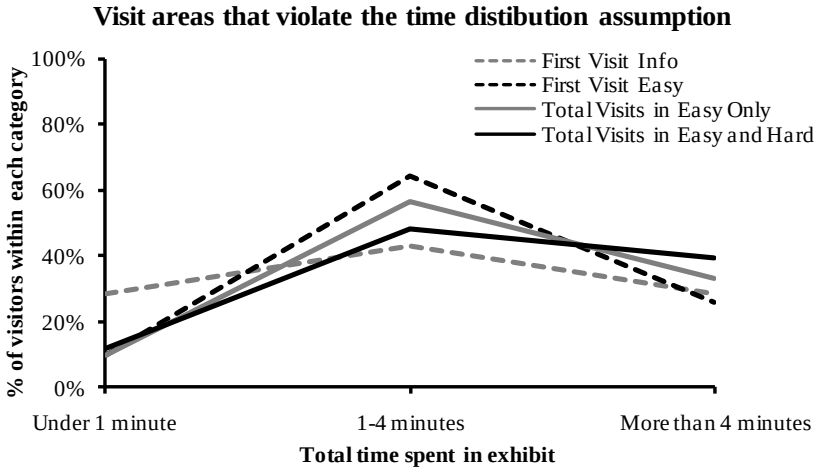


Figure 58. Visit zones in the exhibit that resulted in a large percentage of visitors spending greater amounts of time at the exhibit.

Table 13. Chi-square analysis of the amount of time spent at the exhibit based on first visit zone.

	No	Yes	X^2	p-value
Visited Intro Only			37.621	0.000
0-1 minute	31.0%	93.3%		
1-4 minute	47.4%	3.3%		
More than 4 minute	21.6%	3.3%		
First Visit Easy			18.911	0.000
0-1 minute	53.0%	9.7%		
1-4 minute	31.3%	64.5%		
More than 4 minute	15.7%	25.8%		
First Visit Hard			1.952	0.377
0-1 minute	43.5%	45.2%		
1-4 minute	36.5%	45.2%		
More than 4 minute	20.0%	9.7%		
First Visit Info			4.278	0.118
0-1 minute	47.5%	28.6%		
1-4 minute	37.3%	42.9%		
More than 4 minute	15.3%	28.6%		

combined (Table 13, $\chi^2 = 18.91$, $p < 0.001$). The more normal distribution trend of those groups who visited Easy first is also significantly different than the decreasing time trend of groups who visited Hard first ($\chi^2 = 10.449$, $p = 0.005$).

When looking at time spent at the exhibit for the total visit zones, the question to be answered is if the time spent in the exhibit was influenced by where in the exhibit the visitor navigated during their use, or did the exhibit keep their attention or interest. As seen for the first visit zones, the groups who did not visit the Learning Levels in their total visits or visited Hard only followed the decreasing time distribution assumption trend (Fig 57). For the groups who visited Easy only or Easy&Hard zones, an increasing or more normal distribution of time spent was observed (Fig 58), which is significantly different than the decreasing trend seen when compared to all other groups (Table 14, $\chi^2 = 22.079$, $p < 0.001$). This distinction between time spent in Hard only and the time spent in Easy only or Easy&Hard levels is supported since the visitor distribution of time spent for total visits in Easy and

Easy&Hard are not significantly different ($\chi^2 = 0.423$, $p = 0.810$), but the difference between Hard and Easy&Hard is significant ($\chi^2 = 14.435$, $p = 0.001$).

Similar to the patterns in the first visit groups, groups that did not visit the Learning Levels spent the least amount of time and groups that visited Easy Only was very close to spending the most amount of time at the exhibit (Table 14). Eighty-eight percent of visitors that did not visit any of the Learning Levels spent less than a minute at the exhibit, which differs from the 25% of visitors who spent less than one minute at the exhibit and actually went to the Learning Levels ($\chi^2 = 49.198$, $p < 0.001$). For groups that visited Easy Only, over half spent 1 to 4 minutes at the exhibit, whereas over half of all other groups combined spent less than 1 minute at the exhibit ($\chi^2 = 18.272$, $p < 0.001$).

Table 14. Chi-square analysis of the amount of time spent at the exhibit based on the destination-based total visit zone.

	No	Yes	X^2	p-value
Total Visits Not Easy or Hard				
0-1 minute	25.2%	88.4%	49.198	0.000
1-4 minute	50.5%	9.3%		
More than 4 minute	24.3%	2.3%		
Total Visits in Easy Only				
0-1 minute	52.6%	10.0%	18.272	0.000
1-4 minute	33.6%	56.7%		
More than 4 minute	13.8%	33.3%		
Total Visits In Hard Only				
0-1 minute	43.4%	45.5%	4.47	0.107
1-4 minute	35.4%	48.5%		
More than 4 minute	21.2%	6.1%		
Total Visits in Easy and Hard				
0-1 minute	53.1%	12.1%	22.079	0.000
1-4 minute	35.4%	48.5%		
More than 4 minute	11.5%	39.4%		

A final look at visits and time spent is a comparative analysis to more directly determine influence of a first or total visit zone on time spent at the exhibit. For this analysis, influence comparison was made between first visits to Easy and Hard, total visits to Easy Only and Hard Only, total visits to Easy&Hard and Hard Only, and total visits to Easy&Hard and Easy Only. The magnitude of influence is determined by subtracting the number of visitors in the visit zone listed second within target time category from the number of visitors in the visit zone listed first within the target time category (e.g., # of visitors who visited Hard first and stayed under 1 minute - # of visitors that visited Easy first and stayed under 1 minute = magnitude). A positive magnitude bar indicates there were more groups in the visit type listed first, and a negative magnitude bar indicates there were more groups in the visit type listed second. An equivalence ratio was also calculated, in order to indicate the relative equivalence of the two groups compared, in a similar manner of the magnitude calculation, except that the groups were divided instead of subtracted. An equivalence ratio of 1, coupled with the lack of a magnitude bar, indicates that the two groups being compared are equal in number, and lesser equivalence is indicated as the ratio moves farther away from 1 and approaches 0 for negative magnitudes or higher integers for positive magnitudes.

This type of analysis provides a unique view of the comparison between visit areas. Only in the under 1 minute category is visiting Hard first or Hard Only influential in time spent at the exhibit, as indicated by the negative magnitude bars (Fig 59). The low equivalence ratio also indicates that this influence is relatively strong, with only 1 visitor who visits Easy first or Easy Only staying less than 1 minute for every 5 visitors who visit Hard first or Hard only staying less than 1 minute. The comparison of Hard first or Hard Only to the other zones in the 1 to 4 minute category shows positive magnitudes and almost equal ratios when compared to Easy first and Easy Only, and an equivalent ratio when compared to Easy&Hard. The positive magnitudes indicate that visiting Easy first or Easy Only is influential on more visitors to stay between 1 to 4 minutes, but the strength of this influence is

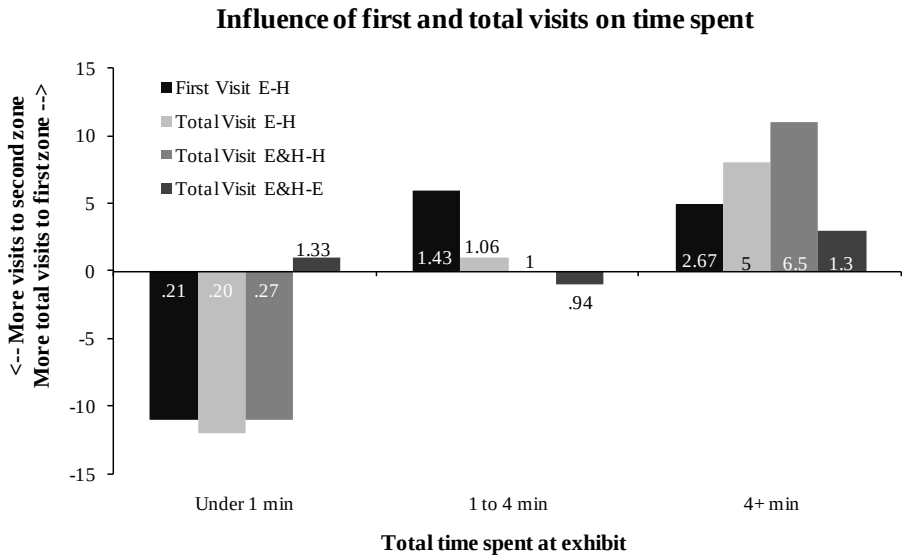


Figure 59. The relative influence of first and total visits on the amount of time spent at the exhibit. The magnitude bars were calculated by subtracting the number of visitors in each category, and the number in each bar is the ratio of those numbers with 1 being equal.

almost equal to that of visiting Hard first or Hard Only. In looking at the visitors who stayed at the exhibit for longer than 4 minutes, visiting Easy first, Easy Only, or Easy&Hard had a much greater and stronger influence on visitors than visiting Hard first or Hard only, as indicated by the large magnitude bars and equivalence ratios. Lastly, the comparison of visiting Easy Only and Easy&Hard showed they have almost equal influence on visitors in all time categories.

Visits and Talk

Comparing the patterns of talk complexity for each first and total visit zone allows us to understand how visitors are using talk in relation to where they are visiting. First visits to Done or Hard (Fig 60) and total visits to Not a Learning Level or Hard Only (Fig 61) both have a decreasing trend of visitors as types of talk increases. For the first visits, groups only engaged in 1 or 2 types of talk, which indicates a lower talk complexity and that potentially little to no socially mediated

learning is happening. In total visits to these zones, the same decreasing trend in visitors is seen, but some visitors do engage in 3 types of talk here. This appearance of 3 types of talk in total visits is not due to the content in the intro pages or Hard, but due to those visitors who visited Info first, then did not visit a Learning Level

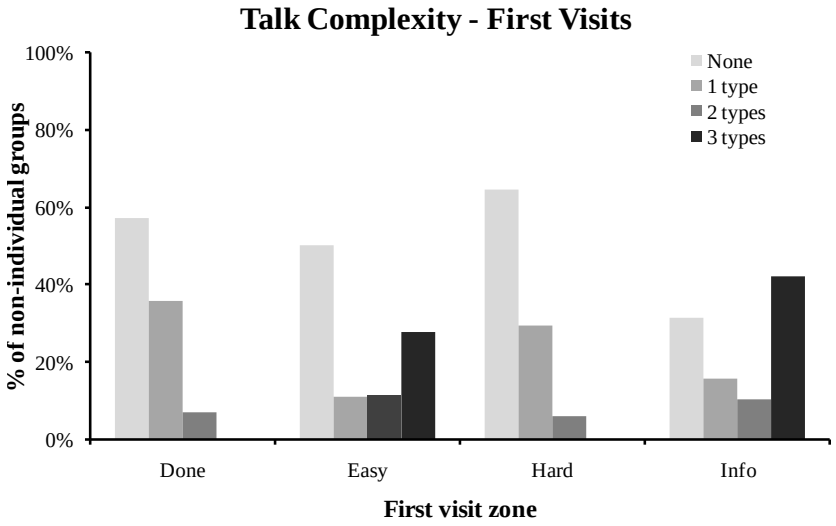


Figure 60. Talk complexity based on the first visit zone.

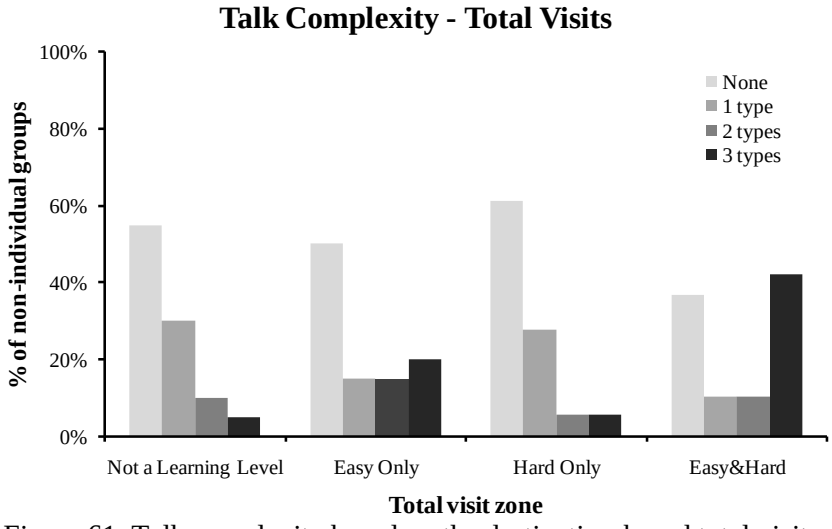


Figure 61. Talk complexity based on the destination-based total visit zone.

subsequently or went to Hard only after Info. Because of this and the fact that 81% of visitors that visit Hard first stay in Hard Only, the talk pattern of visitors that stayed in Hard Only is better represented by the pattern in a first visit to Hard, where there is no engagement in 3 types of talk.

The talk complexity patterns for first visits to Easy and Info, and total visits to Easy Only and Easy&Hard are different than those described above. Of the visitors who talk, the greatest percentage of visitors engaged in 3 types of talk in all of these visit zones. Visiting Info first produces the same talk pattern seen in all visitors, where there is a decrease in visitors from no to 2 types of talk and then an increase to 3 types of talk. The other three visit areas produce a modified version of this pattern, where the percent of visitors is equal for both 1 and 2 types of talk. Another interesting pattern of note is that a first visit to Info and a total visit to Easy&Hard results in more visitors engaging in 3 types of talk than non-individual visitors that do not engage in any talk, which is not seen in any other visit zone or when all visitors are combined.

Time and Talk

Comparing the patterns of talk complexity for each total time spent category allows us to understand how visitors are using talk in relation to how long they are spending at the exhibit. The assumption is that as the amount of time at the exhibit increases, the talking complexity increases, and this is in fact exactly what we see (Fig 62). Only for those that spent less than one minute at the exhibit was a decreasing only trend observed with the majority of visitors not talking decreasing down to no visitors engaging in 3 types of talk. In the 1-4 minute category, trend is exactly the same as what is seen for all visitors, where the largest percentage of visitors do not engage in talk, but of those that do, the highest percentage engage in 1 type, the smallest percentage of visitors engage in 2 types of talk, and the percent of visitors who engage in 3 types of talk is between those two. Finally, for the visitors in the 4+

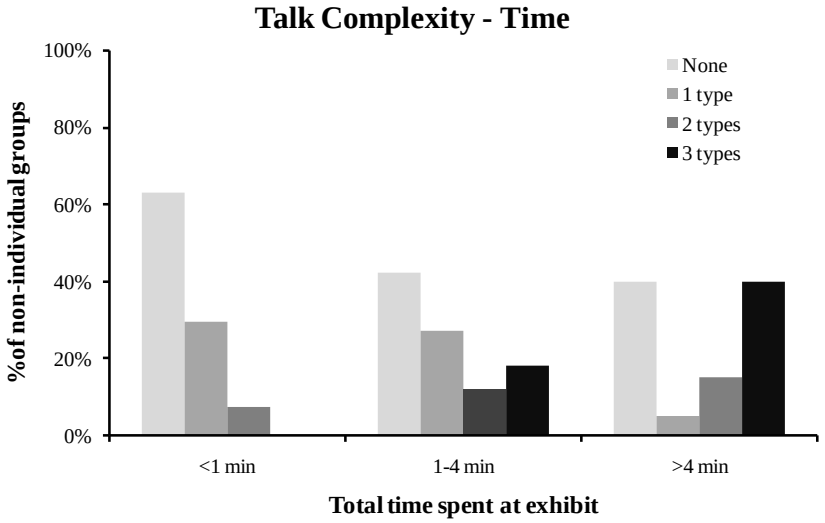


Figure 62. Talk complexity based on the amount of time spent at the exhibit.

minute category, an extremely unique trend of increasing visitors from 1 type to 3 types of talking occurred; the percentage of 4+ minute visitors that engage in 1 type of talk is the same as the percentage of under 1 minute visitors that engage with 2 types of talk, which is the most complex type of talking for those groups. Even though the not talking category was the highest percentage of visitors in the 4+ minute category, removing the individuals shows that the percent of non-individual visitors that do not talk is the same as the percent of visitors that engage in learning indicating talk.

Synthesis

The interest comparing the use and resulting behaviors of that use of Easy and Hard Learning Level zones is to discern, if possible, if in fact learning is happening in these critical zones that were designed with the intent to teach and inform. First, there must be an understanding of the design differences between these two zones. The distinction between the Easy and Hard zones was primarily due to the placement of the buttons on the second intro page. Text indicated that the Easy zone levels were for

those that "were unsure of how to understand line graphs", and the Hard zone levels were to look at data from Yaquina Bay. To visitors, there was no other indication on subsequent pages of the distinction between levels except for how the buttons were ordered on the side navigation bar. Content and presentation-wise, however, there very much is a distinction between the zones. The Easy zone levels both involve the user by asking questions and providing answers based on user input; however, the Hard levels do not ask for any user input, only for them to answer questions or solve problems posed, and are less interactive in that respect. Levels 4 and 5, though, do ask the visitor to interact with line graphs obtained from the web, so whereas the exhibit does not have internal interaction, it is asking for interaction external to the exhibit. So the distinction between the Easy and Hard zones are valid in comparing the two types/modes of interaction, those levels that are based on user input and those that are not.

Knowing the typical demographics of informal learning facilities, in general, and HMSC VC, specifically, yielded some hypotheses and expectations on how visitors would interact with the exhibit. In an average informal learning site, it would be expected that the Easy zone would be the most appropriate for most visitors, but because of the large percentage of visitors at HMSC that have college degrees, we might expect to see more groups interacting with the more advanced levels that at another free-choice learning facility; however, because of the large percentage of groups observed are individual youths or part of a multi-generational group, which the majority of which have youth in them, we still expect the majority of groups to visit the easier levels, which are more appropriate for the youth age classes. What was actually seen, though, is that all the first visit zones, Done, Easy, Hard and Info, on the whole were equally visited by users, and therefore show no preference of one zone over the other after following the Home to Intro pages path. Even though not seen in the broader zones, a preference of starting at L1, probably the one of the most appropriate level of difficulty for most visitors, is shown, followed by the Estuary page, which is also appropriate for many visitors to start since it relates background

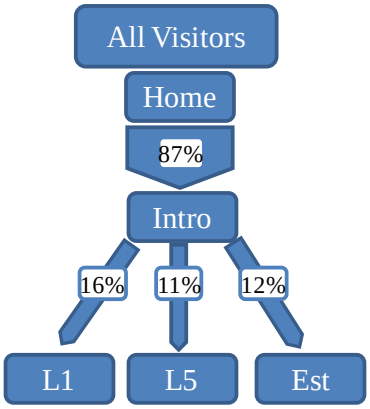


Figure 63. The first visit paths to specific exhibit levels for all observed visitors. The percentages are the percent of all the visitors (fall and winter combined, n=146) that followed that visit path, and the arrow thickness corresponds to that percent. Only the paths with greater than 10% of visitors were included.

information to the visitors about what they are about to interact with (Fig 63). Where it might be expected that another level in Easy or page in Info ranks as the third most common first visit level, instead we see that L5, the hardest level that requires the most expert knowledge and is very skill intensive, is the third level most commonly visited first. This observation can have several explanations: the highly college educated adult crowd of HMSC is jumping ahead and going to the online (real-time) data, perhaps they wanted to check out what the hardest level is to judge if they could attempt it first, or because of text on the intro page about learning YB's story, which could have misled some visitors into thinking that there would be an actual story there from a scientist and instead of interacting with data. The following discussions about Easy and Hard will attempt to tease out what visitors are doing while in these levels and if their behaviors indicate that learning is happening.

Easy

The first part of this discussion is the relationship between time and visiting Easy. Groups that visit Easy first do not follow the expected time spent at the exhibit trend with the majority spending between 1 to 4 minutes at the exhibit, with a large

percentage of the rest spending more than 4 minutes at the exhibit. In the transition from a first visit to Easy to a total visit in Easy Only, a small percentage of visitors are lost to total visits in Easy&Hard and a smaller percentage of visitors are gained who visited Info first, but the time trend is basically the same, except for an decrease in 1-4 minute visitors and an increase in 4 or more minute visitors. Since we know that spending more time at the exhibit increases the talk complexity, so this shift in time spent is an initial sign that learning could be occurring in Easy. We also see that visiting Easy first or Easy Only has a stronger influence on visitors than Hard to spend more than 4 minutes at the exhibit, so it is no surprise that there is a dramatic shift in time spent from a first visit in Hard to a total visit to Easy&Hard. Of the visitors who visit Hard first, less than 10% spend more than 4 minutes, and by adding a visit to Easy during the course of their interaction, this shifts to less than 15% of Easy&Hard visitors spending less than 1 minute at the exhibit. Another way to frame this dramatic shift is that almost half of visitors that visit Hard first spend less than a minute at the exhibit, whereas almost half of the visitors that visit Easy&Hard in total spend more than 4 minutes at the exhibit. The time spent by visitors in Easy&Hard is also different than all the other visitors combined, so visiting Easy after a first visit to Hard results in a significant shift and in the direction of potentially more complex talk.

So, is learning happening in Easy? Most likely. The learning indicating behavior we are using here is talk complexity where engagement in 3 types of talk indicates that learning is happening. A tentative conclusion of Learning Claim 2 was that engagement in 3 types of talk is appropriate for multi-generational groups, and that engagement in 2 types of talk would be a better indicator of learning for Adult Peers; however this is not proven, so only the one proven measure of learning, engagement in 3 types of talk, will be used here. As expected, we see that talk complexity increases as time spent at the exhibit increases, and since less than 10% of visitors who visited Easy first or Easy Only spent less than 1 minute at the exhibit, where no learning indicating talk occurred, we would expect to see indications of learning. With the percent of visitors that engage in talk equal to the percent of non-

individual visitors that do not engage in talk for both types of visits to Easy, this is a strong sign that there are at least initial stages of learning occurring; however, the fact that the highest percentage of visitors engaged in 3 types of talk for both visit types serves as an indicator that learning is in fact happening in groups that visit Easy.

Hard

With the equal first visit distribution majority of users visiting Easy or Info first staying at the exhibit for longer than 1 minute, the time spent when Done and Hard first is low, which is expected for those that leave, but does not fit the initial expectation for Hard. Since we anticipated that the levels in Hard would encourage visitors to investigate the data online, the idea was that visitors may be spending more time (than they did) to play with the online data. But what is seen for both first and total visits to Hard is that an equal number of groups spend under 1 min and 1-4 min at the exhibit with almost none spending more than 4 minutes. The majority of groups that visit Hard first stay there, and coupled with the low amount of time spent and the stronger influence than Easy on visitors to stay at the exhibit for under 1 minute, this indicates that there is not a lot of elements in the Hard levels hooking visitors to stay at the exhibit or seek out other levels where they may spend more time at. Visiting Hard first also resulted in lower talking complexity with no groups engaging in 3 types of talking, which is very similar to groups that left the exhibit after the Intro pages, and is an indicator that learning is not occurring in Hard. The groups that visited Hard only had some groups that engaged in 3 types of talking, but since not Learning Level groups also gained groups that engaged in 3 types, this increase in talking complexity is due to the groups that visited Info first and then navigated to either one of those total visit zones; so this increase in talking complexity is not due to the groups that first visited and stayed in Hard, but by the inclusion of those groups that also went to Info first, with the caveat that it is unknown where these first visit Info groups talked. They may have engaged in all three types of talk in the Info pages then not talked

when at Hard, vice versa, or some hybrid. These groups show us that learning is potentially happening, albeit for only a very small percent of the population, in Hard, which could be the population we are trying to target with these harder levels.

Conclusions

The initial presentation of the first and total visit data posed two questions: do first impressions matter (yes) and does the exhibit keep visitors' interest (depends)? The first impressions are seen in the time spent, with more time spent at the exhibit by users that visit Easy first and less time spent by those that visit Hard first. We also know that almost 1 in 5 groups that visit Easy first show signs of learning, whereas visiting Hard alone does not and only the combination of visiting the Info pages and Hard or both Easy&Hard during a group's interaction will result in learning indicating talk. As for if the exhibit holds a visitor's attention, that depends on the first impression. The first impression that Easy makes on visitors keeps them there, as evidenced by the time spent by those that visit Easy Only and Easy&Hard to an extent, but the first impression that Hard makes on visitors results in shorter visit times and less observed learning.

But what is causing this? These findings suggest that the design of the exhibit is facilitating learning experiences, so not only useful as a scaffolding tool for Multi-generational groups, but is also effective tool that supports behavior that is indicative of learning- We see this primarily in the Easy levels more so than the Hard levels, indicating that these are either more appropriate for the visitor knowledge and skill level in a science center, or the elements and activities in Easy are more in line with their interests and motivations.

One final question remains about the limited number of groups that visited Hard and engaged in learning-indicating talk. Going back to visitor demographics, seems that the college educated visitors that the Hard levels are targeted to are not using the exhibit as part of a Peer group but instead as a Multi-generational group and

staying in the Easy levels. Another conjecture about the few Peer groups that are visiting the Hard levels for an appropriate amount of time to actually complete any of the activities is that they are already familiar with the information and do not have to engage in learning talk, or they are using as an individual. One important finding here, though is that no visitors accessed the web and used it in the anticipated or appropriate manner, which leads to the conclusion that the structure and design of the Hard levels are not appropriate for a free-choice learning setting, and the hardest level for future exhibits should be Level 3.

Learning Claim 4: Modification to the exhibit resulted in anticipated changes in visitor use and talk in the Easy levels, but not in the Hard levels

Visits in V2.0 and V3.0 by all visitors

When comparing the fall evaluation to the winter evaluation, different patterns of first visits are seen. The overall distribution of visitors in the four general first visit zones is significantly different (Table 15, $\chi^2 = 7.73$, $p = 0.05$) between fall (V2.0) and winter (V3.0) with Hard (31%) and Done (31%) the most common during the fall and Easy (36%) and Info (25%) the most common during the winter (Fig 8-1). However, Easy was the only individual zone that had a significant change in visitors ($\chi^2 = 4.96$, $p = 0.026$), from 14% of visitors in the fall and 29% of visitors in the winter (Table 16).

Visitors also had different usage patterns for total visits as well. The first look at total visits is destination-based, or where visitors ended up regardless of where their first visit was. When both evaluation rounds are combined, besides the most common destination to not to visit a Learning Level, visitors show no outstanding preference of zones within the Learning Levels since the percent of visitors in Easy Only, Hard Only, and Easy&Hard are fairly even (Fig 64). However, even though not significant ($\chi^2 = 7.078$, $p = 0.069$), visitors in the fall showed a preference by most commonly

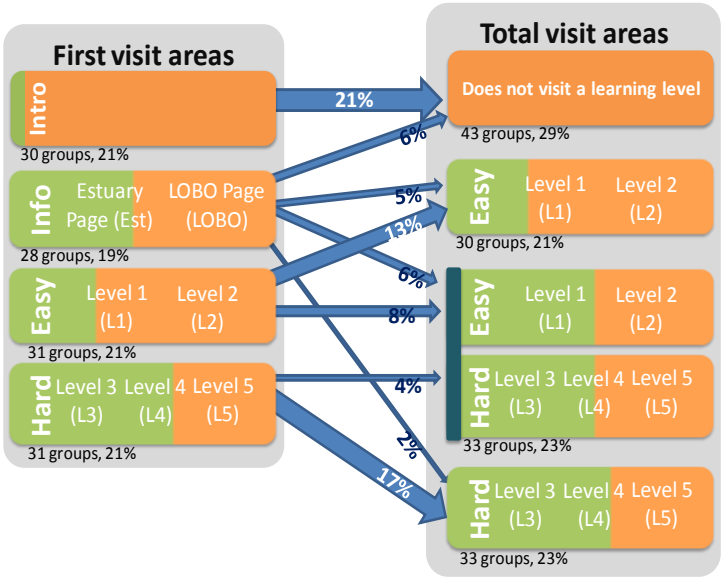


Figure 64. Path-based total visits from all four first visit zones. Percentage of total visitors (n=146) is indicated on the arrows, which have variable width based on the percentage. The green represents the percent of fall visitors in that visit area, and orange represents the winter visitors.

Table 15. Chi-square analysis of first and destination-based total visits for each evaluation round.

	Fall 2008	Winter 2009	X^2	p-value
First Visit			7.729	0.052
Intro Only	31.1%	18.6%		
Easy	16.4%	35.6%		
Hard	31.1%	20.3%		
Info	21.3%	25.4%		
Total Visits			7.078	0.069
Not Easy or Hard	33.8%	27.9%		
Easy Only	12.7%	30.9%		
Hard Only	28.2%	19.1%		
Easy and Hard	25.4%	22.1%		

Table 16. Chi-square analysis of first visit zones between evaluation rounds.

		Fall 2008	Winter 2009	X^2	p-value
Visited Intro Only				2.685	0.101
	No	74.0%	84.9%		
	Yes	26.0%	15.1%		
First Visit Easy				4.955	0.026
	No	86.3%	71.2%		
	Yes	13.7%	28.8%		
First Visit Hard				2.007	0.157
	No	74.0%	83.6%		
	Yes	26.0%	16.4%		
First Visit Info				.177	0.674
	No	82.2%	79.5%		
	Yes	17.8%	20.5%		

Table 17. Chi-square analysis of total visit zones between evaluation rounds.

	Fall 2008	Winter 2009	X^2	p-value
Total Visits Not Easy or Hard			0.824	0.364
No	67.1%	74.0%		
Yes	32.9%	26.0%		
Total Visits in Easy Only			6.041	0.014
No	87.7%	71.2%		
Yes	12.3%	28.8%		
Total Visits In Hard Only			1.918	0.166
No	72.6%	82.2%		
Yes	27.4%	17.8%		
Total Visits in Easy and Hard			0.352	0.553
No	75.3%	79.5%		
Yes	24.7%	20.5%		

visiting not a Learning Level or Hard Only with Easy Only the least visited zone, and visitors in the winter had a preference for visiting Easy Only or not in a Learning Level the most with Hard Only the least visited (Table 15). Like seen in first visits,

the increase of visitors to Easy Only from 12% in the fall to 29% in the winter was significant (Table 17, $\chi^2 = 6.041$, $p = 0.014$).

The first visit patterns were seen in some of the group sizes and types, but not all. Individuals and Groups of 3 or more visited Done most frequently in the fall and Easy most frequently during the winter, just like all visitors combined (Fig 65). The greatest percentage of Pairs, however, visited Hard first in the fall, which was the second most frequented first visit zone for all visitors, and Info in the winter. Looking at group types we see that both types of Individuals visited Done the most in the fall, but in the winter the large percentage of all Individuals is actually from Individual Adults since Individual Youth visit Hard first most frequently in the winter (Fig 66). Peers and Multi-generational groups both visited Hard first most frequently during the fall, but even though both groups had an increase in first visits to Easy in the winter, Multi-generational groups visited Easy first most frequently during the winter whereas Peers visited Info first.

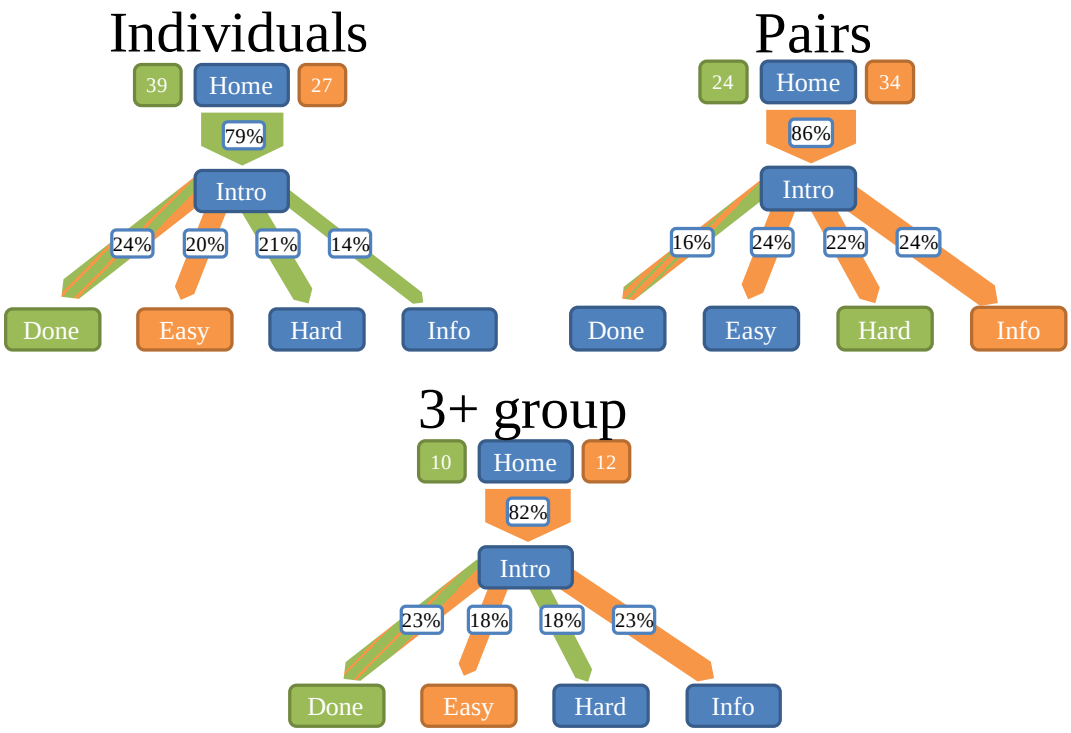


Figure 65. Overall visit paths for each group size. Green is the fall and orange is the winter. The numbers on either side of the Home box is the total number of visitors in that group type for fall and winter. The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path.

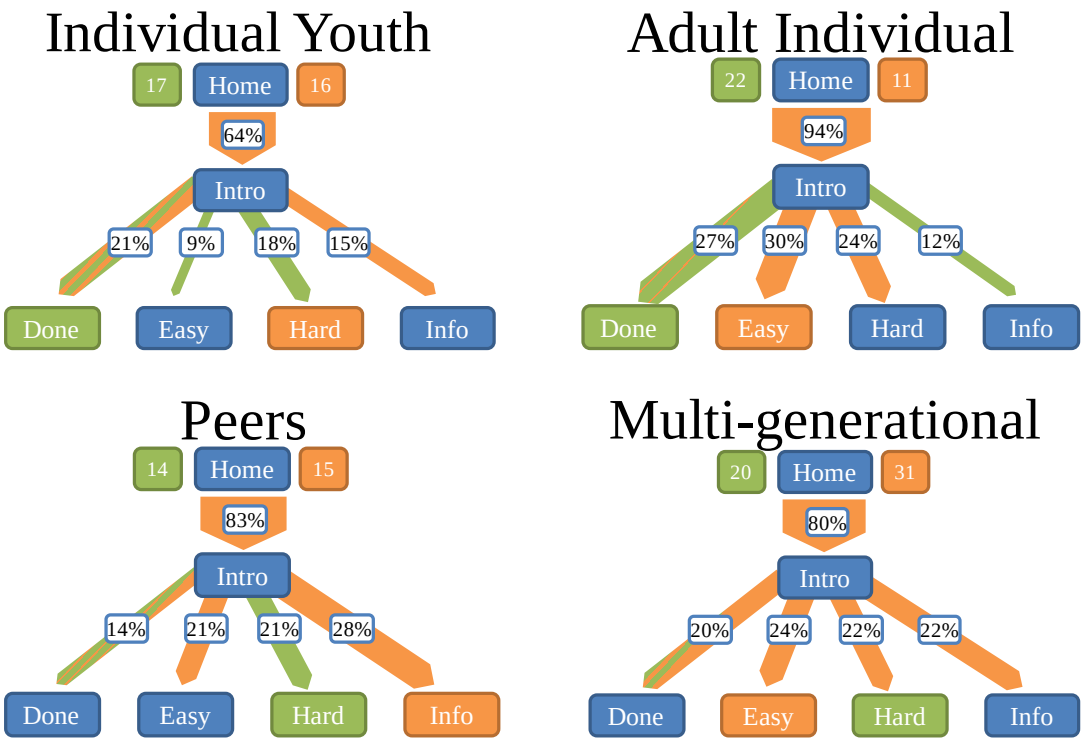


Figure 66. Overall visit paths for each group type. Green is the fall and orange is the winter. The numbers on either side of the Home box is the total number of visitors in that group type for fall (green) and winter (orange). The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path.

Since the main interest is determining use in the Learning Levels, the rest of this analysis is focused on only those groups that start in either Easy or Hard as a first visit to look at where they visit subsequently after that. Thus, this analysis is path-based total visits, or where groups moved to after they started and is dependent on the first visit. The majority of all visitors, as well as visitors from fall and winter, that start in one of these first visit zones stay in that zone for their entire interaction with no difference between the percent of groups in the fall or winter (Table 18, Easy: χ^2 = 0.47, p = 0.492; Hard: χ^2 = 0.091, p = 0.763). However, we do see a bigger change in percent of visitors in Easy Only, with 70% of Easy first visits staying in Easy Only

during the fall and 57% in the winter, than the change in Hard Only, where 79% of Hard first visits in the fall stayed in Hard only and 83% stayed in the winter (Table 18). These percentages translate differently when, instead of calculated based on the total in each evaluation round, the percentages are calculated based on the total of visitors for each path (Table 19). The path based percentages show that the majority of visitors to Easy Only or Easy&Hard are from the winter and that the majority of visitors to Hard Only are from the fall (Fig 66).

Table 18. Chi-square analysis of path-based total visits for first visits to Easy or Hard in the fall and winter.

	Fall 2008	Winter 2009	X^2	p-value
First Visit Easy			.472	0.492
Total Visit Easy Only	70.0%	57.1%		
Total Visit Easy and Hard	30.0%	42.9%		
First Visit Hard			.091	0.763
Total Visit Hard Only	78.9%	83.3%		
Total Visit Easy and Hard	21.1%	16.7%		

Table 19. Numbers used in calculating percentages for Fig 9-3 and Table 9-4.

	Fall 2008	Winter 2009	Total for Fig 9-3
First Visit Easy			
Total Visit Easy Only	7	12	19
Total Visit Easy&Hard	3	9	12
Total for Table 9-4	10	21	31
First Visit Hard			
Total Visit Hard Only	15	10	25
Total Visit Easy&Hard	4	2	6
Total for Table 9-4	19	12	31

For the path-based changes from fall to winter, once again difference were seen between group sizes and types. Like for all visitors, all three group sizes most commonly followed the path from visiting Hard first and staying in Hard Only in the fall and the greatest percentage of Individuals and Groups of 3 or more followed the path from visiting Easy first and staying in Easy Only; Pair groups were different in the winter by visiting Easy first and then also visiting a level in Hard to have Easy&Hard as a total visit (Fig 67). Individual Adults, Peers and Multi-generational groups also followed the Hard first to Hard Only path most frequently in the fall, with Individual Adults and Multi-generational groups following the most common path for

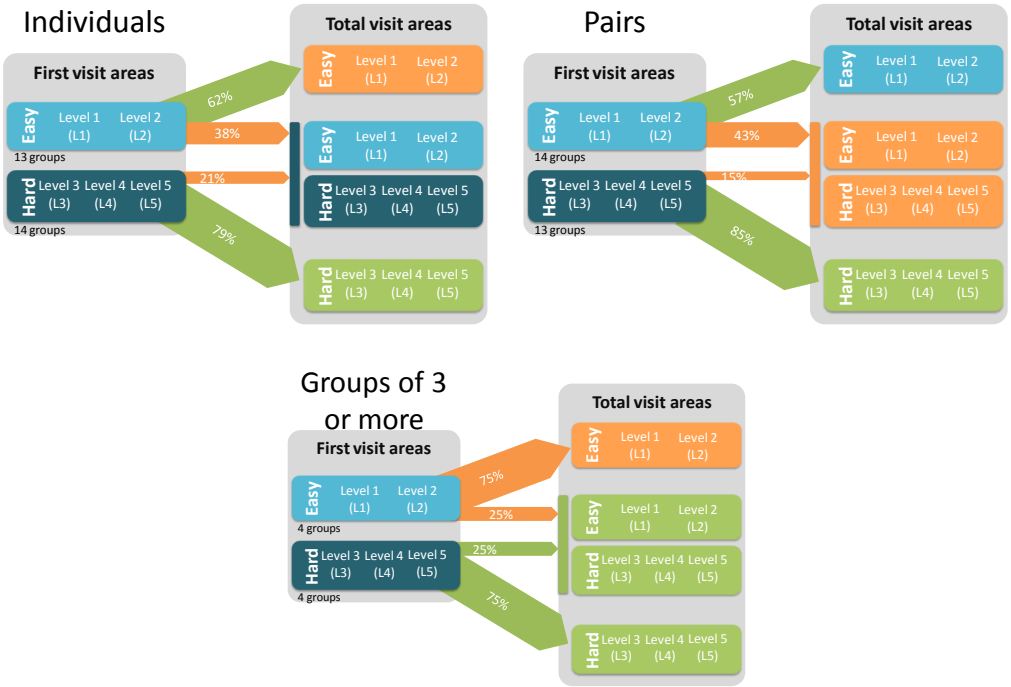


Figure 67. Total visit paths for each group size. Green is the fall and orange is the winter. The numbers from each first visit zone are indicated below the first visit zone boxes. The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path. The green and orange total visit boxes indicate the most common path in the fall (green) and the winter (orange).

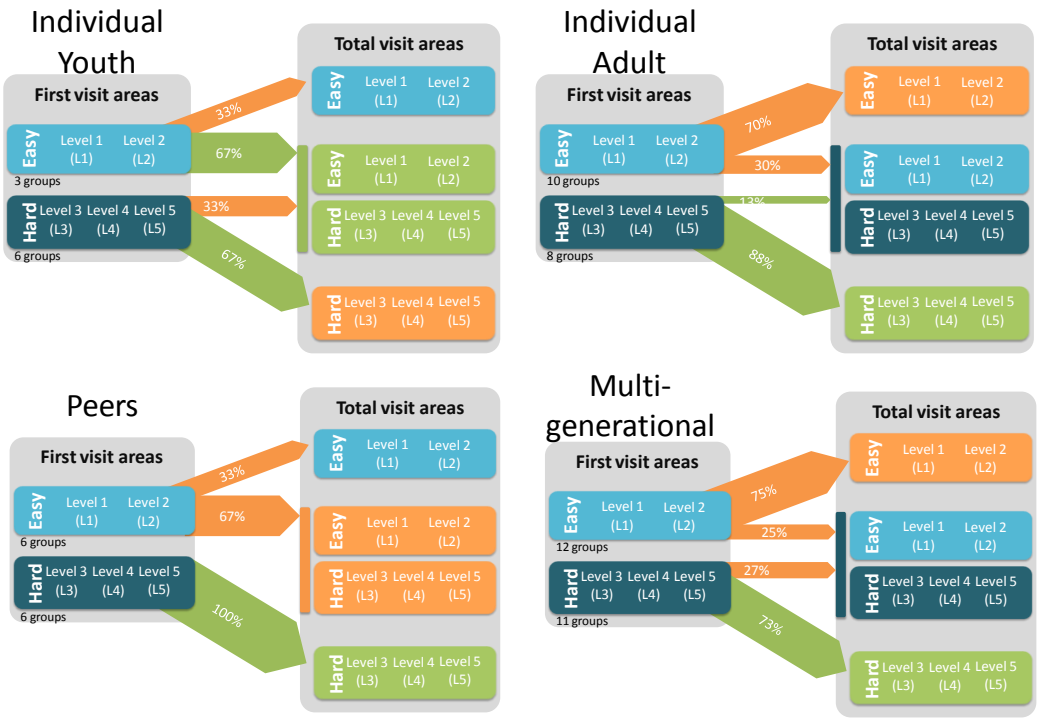


Figure 68. Total visit paths for each group type. Green is the fall and orange is the winter. The numbers from each first visit zone are indicated below the first visit zone boxes. The percentages are the percent of the total group type (fall and winter combined) that followed that visit path, and the arrow thickness corresponds with that percent. Within each arrow, the percent coverage of the green and orange represent the fall:winter breakdown within that visit path. The green and orange total visit boxes indicate the most common path in the fall (green) and the winter (orange).

all visitors in the winter, from Easy first to Easy Only (Fig 68); Peers most commonly followed the path from Easy first to Easy&Hard in the winter. Individual Youth were very different from the other group types by most commonly following the Easy first to Easy&Hard path in the fall and the Hard first to Hard Only path in the winter (Fig 68).

Time spent in fall and winter by all visitors

The standard distribution of visitors as time spent at the exhibit increased was a decreasing trend, which is seen when all visitors are combined (Fig 69). The time spent by visitors observed using Version 2 in the fall also fit within this expected trend; 52% spent up to 1 minute, 27% spent 1-4 minutes, and 21% spent more than 4 minutes (Fig 69). However, the distribution of time spent at the exhibit by visitors observed using Version 3 during the winter violated this assumption and is significantly different ($\chi^2 = 7.43$, $p = 0.024$) than the fall trend; with 36% spending up to 1 minute, 49 % spending 1 to 4 minutes, and 15% spending more than 4 minutes, the trend looks more like a normal distribution than the assumed decreasing trend (Fig 69). The average time spent at the exhibit was 2.5 minutes for all observed visitors, 2.7 minutes with a 21 minute maximum time during the fall, and 2.4 minutes with a 16 minute maximum time during the winter. Both evaluation rounds had a time minimum spent that was less than 10 seconds.

A pattern seen in all group sizes (Fig 70) and types (Fig 71), regardless of the overall time trend, is an increase from fall to winter of visitors in the 1 to 4 minute category, with most groups having a decrease in the under 1 minute category.

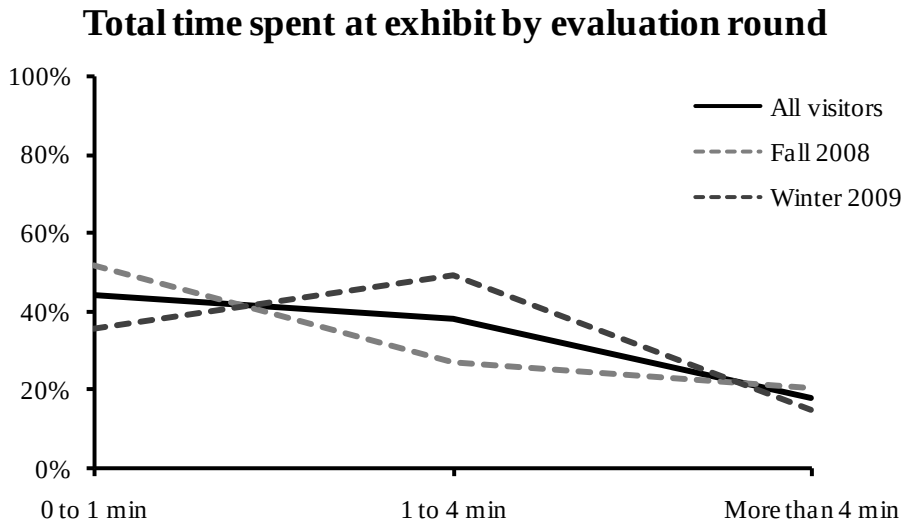


Figure 69. Total time spent at the exhibit for both evaluation rounds..

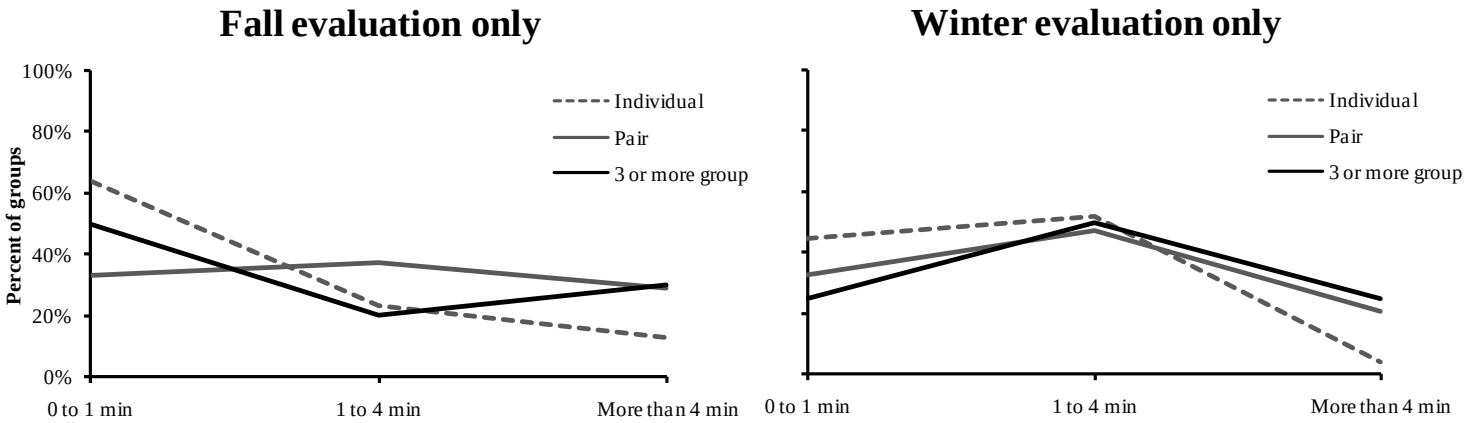


Figure 70. Total time spent at the exhibit by group size for fall and winter.

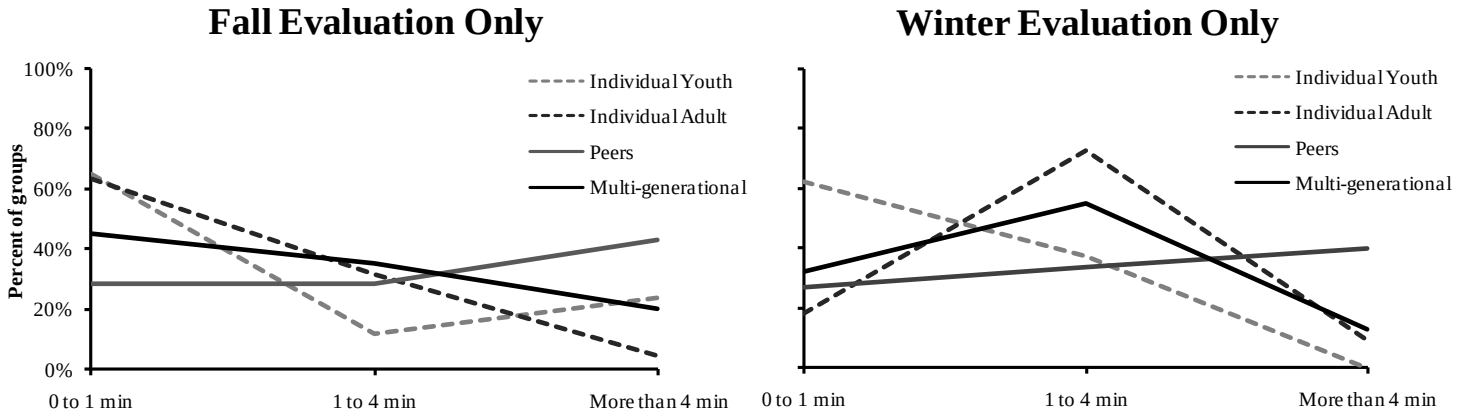


Figure 71. Total time spent at the exhibit by group type for fall and winter.

Combined Individuals had a decreasing time distribution for both evaluations (Fig 70), but looking at the different age classes of individuals, Individual Adults actually had a normally distributed time distribution in the winter, which is not seen by either Individual age groups in the fall or by Individual Youth in the winter (Fig 71). Pairs are evenly to normally distributed between the three time categories in the fall which changes to a more defined normal distribution in the winter, and Groups of 3 or more change from a decreasing trend in the fall to a normally distributed trend in the winter (Fig 70). Multi-generational groups also changed from a decreasing trend in the fall to a normally distributed trend in the winter, and Peer groups had a unique increasing trend for both fall and winter (Fig 71).

Finally, the last time comparison between the evaluation rounds to be made is for the first and total visits. Both first and total visits in Easy maintained the normal distribution curve with the greatest percent of visitors spending 1-4 minutes at the exhibit; however, the percent of groups in the under 1 minute category decreased from fall to winter and increased the percent of groups in the 1 to 4 minute category from fall to winter, thereby enhancing the normal distribution curve and exhibiting a shift to more time spent at the exhibit on the whole (Fig 72). For first and total visits to Hard, most of the time distributions were the predicted decreasing trend as time increases except for total visits to Hard Only in the winter, where there was a shift of visitors from the under 1 minute category to the 1 to 4 minutes category, creating a trend that looked more normally distributed (Fig 73). The percentage of visitors in the 4 or more minutes category for the total visits to Hard only during the winter were similar to the other first and total visits to Hard (Fig 73). Lastly, the total visits to Easy&Hard had either an increasing trend during the fall, with the majority of the visitors in the more than 4 minutes category, or a normally distributed curve during the winter, with the majority of the visitors in the 1 to 4 minute category (Fig 74).

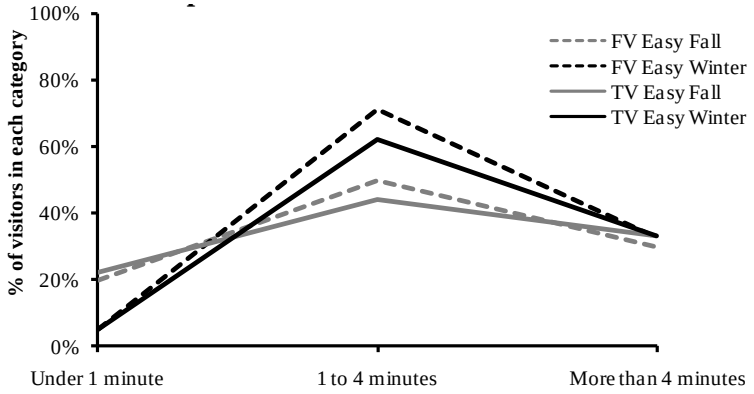


Figure 72. Total time spent at the exhibit for first and total visits to Easy.

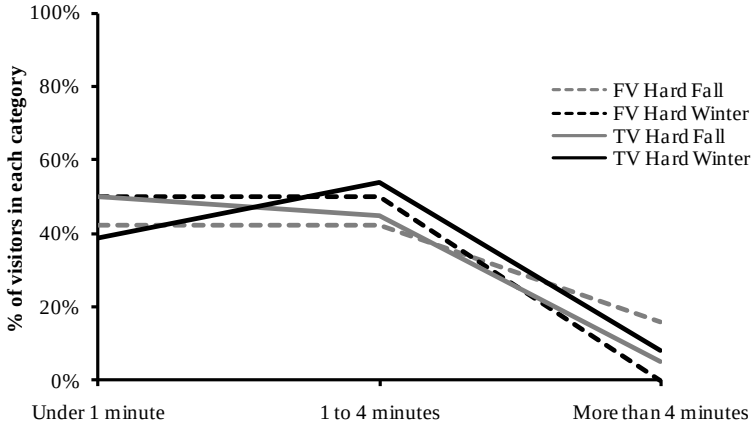


Figure 73. Total time spent at the exhibit for first and total visits to Hard.

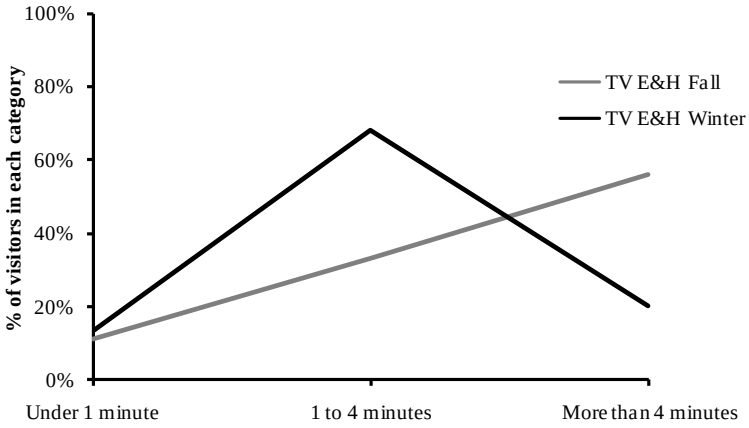


Figure 74. Total time spent at the exhibit for total visits to Easy&Hard.

Talk complexity

Visitors in the fall and winter show the same talk complexity pattern: the majority of the visitors engage in no talking with a decrease in visitors to two types of talking, and then the number of visitors increase to three types of talking (Fig 75). Talk complexity increased from fall to winter since the greatest percentage of visitors engaged in 1 type of talking in the fall and 3 types of talking in the winter (Fig 75). This shift in talk complexity of an increase in 3 types is also seen in Multi-generational groups (Fig 76) and a shift to 2 types of talking in Peer groups (Fig 77).

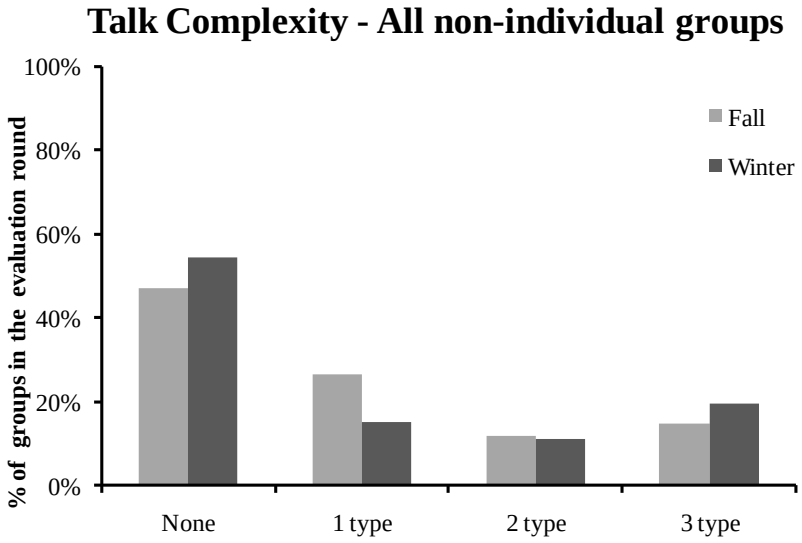


Figure 75. The talk complexity for all non-individual groups in the fall (34 groups) and winter (46 groups) evaluation rounds.

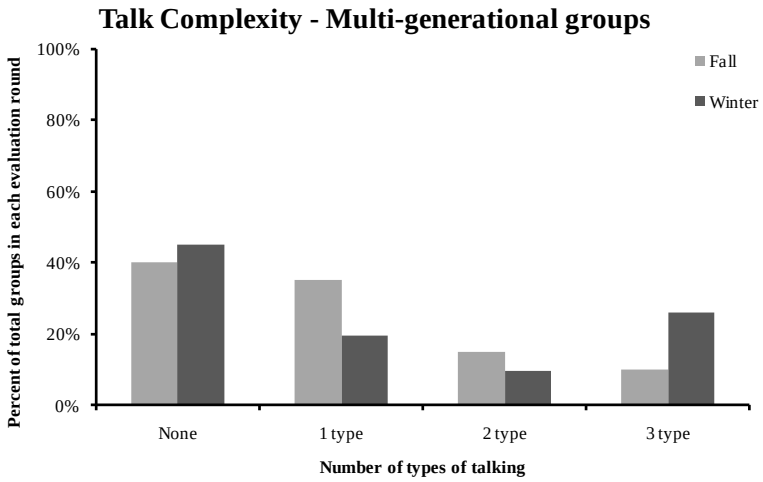


Figure 76. Talk complexity for fall and winter Multi-generational groups.

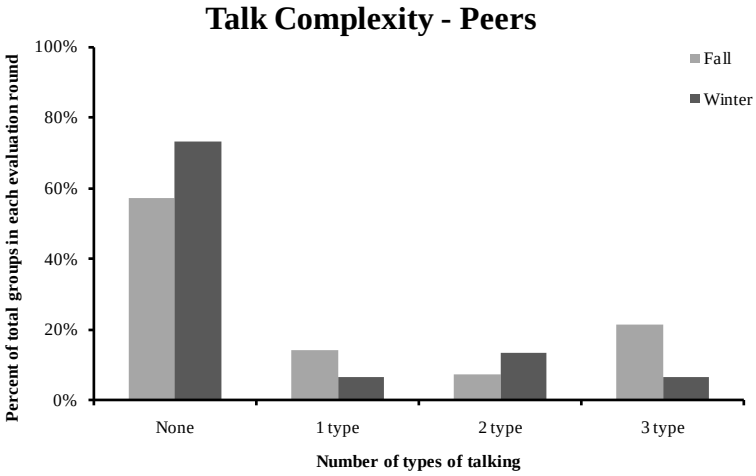


Figure 77. Talk complexity for fall and winter Peer groups.

Talk and time

Talk complexity in general increases as time spent at the exhibit increases. Visitors that spent less than 1 minute during both evaluations and 1 to 4 minute visitors in the fall had the lowest complexity of talk with the greatest percentage of visitors who did talk engage in 1 type and no visitors engaging in 3 types of talk (Fig

78). Winter visitors who spent 1 to 4 minutes showed an increase in talk complexity from the fall with a decrease of engagement in 1 type of talk and an increase in 2 and 3 types of talk. For the groups that spent more than 4 minutes, the complexity of talk was high for both evaluations since the greatest percentage of visitors engaged in 3 types of talk and 1 type of talk had the least number of visitors; however, all types of talk decreased from fall to winter, with none engaging in 1 type of talk in the winter, indicating that less visitors who spent more than 4 minutes in the winter talked than in the fall.

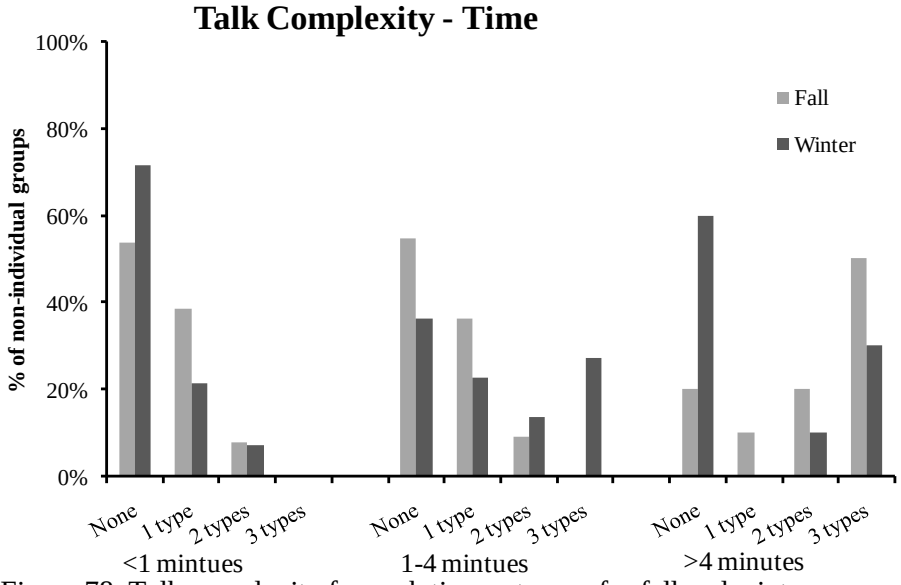


Figure 78. Talk complexity for each time category for fall and winter.

Talk and first visits

The patterns of talk complexity for first visits to Done or Hard are similar to each other whereas the talk patterns for groups that visited Easy or Info first appear to be slightly different (Fig 79). For both Done and Hard, both fall and winter had a decreasing trend of visitors as talk complexity increased with no visitors in the winter

in Done or in the fall in Hard engaging in 2 types of talk, and no visitors from either evaluation engaging in 3 types of talk. Talk complexity did increase from fall to winter in Hard, but less talking happened in the groups that visited only the Intro pages during the winter than the fall.

For those that visited Easy first, the fall talk complexity has a decreasing trend like seen for Done or Hard and winter has the same trend seen by all combined visitors where the number of visitors decrease from 1 to 2 types and then increase to 3 types of talking (Fig 79). Of those that talked while visiting Easy first in the fall, an equal amount engaged in 1 or 2 types of talk and no groups engaged in three types of talk. Winter groups visiting Easy first had the majority of groups engaged with 3 types of talk, with a slight decrease in 1 type of talk from the fall and a greater decrease in 2 types of talk from the fall.

Finally, for groups that visited the Info pages first, the distribution of visitors looks slightly different (Fig 79). All non-individual groups in the fall that visited Intro engaged in at least 2 types of talk with the majority engaging in 3 types. In the winter, visitors engaged in 1, 2 and 3 types of talking with an even percentage of

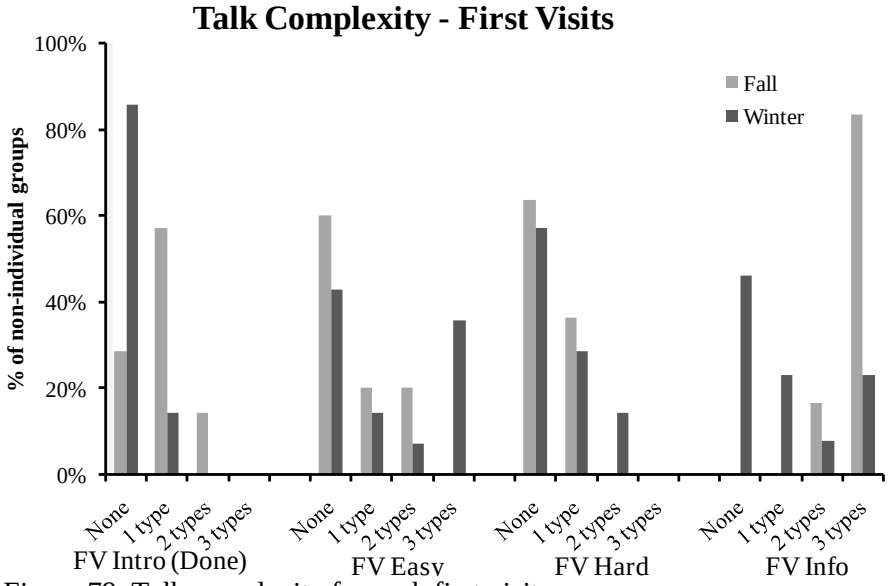


Figure 79. Talk complexity for each first visit zone.

groups engaging in 1 and 3 types of talking. Talk complexity seems to have decreased from fall to winter for those that visited Info first.

Talk and total visits

Lastly are the patterns of numbers of types of talks against total visit zones (Fig 80). For groups whose total visits were not in any of the Learning Levels, both fall and winter had decreasing trends, with the greatest number of groups engaged in 1 type in both fall and winter, but none engaged in 3 types during the fall and equal percentages of groups engaged in 2 or 3 types in the winter. Like in first visits, this same pattern was seen for the groups that visited Hard Only, except in the fall groups only engaged in 1 type of talk (Fig 80). However, where talk complexity increased from fall to winter in both visit zones, in Hard Only the engagement in talk also increased since there are less non-talking groups in the winter than in the fall.

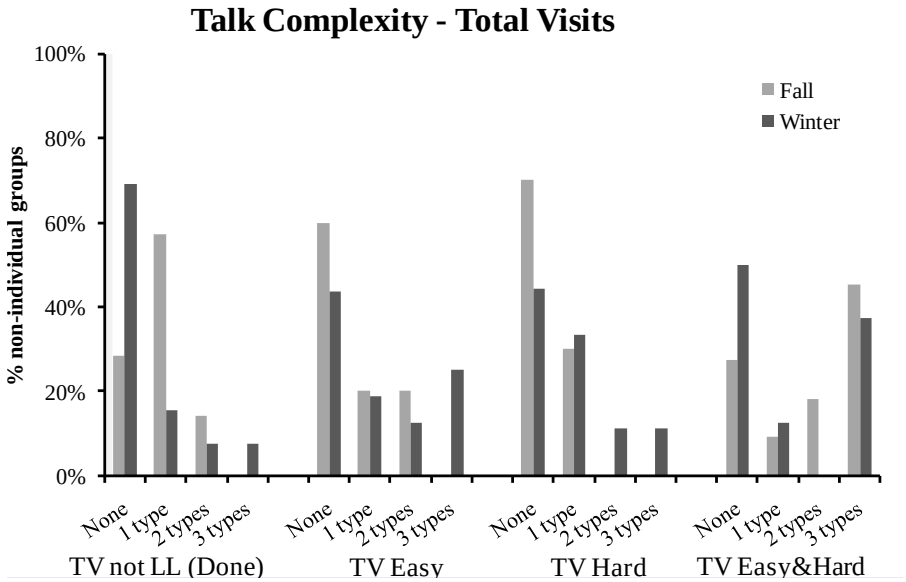


Figure 80. Talk complexity for each total visit zone.

The trend seen for the groups that visited Easy Only is very similar to trend seen in first visits to Easy, where fall had a decreasing trend and winter had a decreasing trend to 2 types of talking with an increase in 3 types of talking (Fig 80). Of those that talked in the fall, there were equal percentages engaged in 1 or 2 types of talking and none in 3 types, which had an increasing shift in the winter where the highest percentage of visitors engaged in 3 types of talking.

Finally, for the groups that visited Easy&Hard, fall had a decrease of groups from no to 1 type of talk and an increase from 1 to 3 types of talk, whereas winter had a decrease from no to 2 types of talk and an increase from 2 to 3 types of talk (Fig 80). Of those that talked, for both the fall and winter the greatest percentage engaged in 3 types with the least in the fall engaging in 1 type and no groups in the winter engaging in 2 types. This indicates that talk complexity for those that visit both Easy&Hard decreased from the fall to the winter.

Synthesis

Easy

As mentioned in the beginning section of this claim, one of the goals in the modifications for V3.0 in the winter was to increase visitor engagement with the Easy levels first instead of the Hard levels first. The first indication that we successfully achieved this goal is the significant increase in first and total visits Easy from fall to winter. Because the majority of groups that visit Easy first stay in Easy Only during their entire interaction with the exhibit, we see similar changes in visitor use and behavior for both of these visit zones so they will be discussed together. However, just because more groups are visiting these zones doesn't automatically mean that the quality of the visit, as seen in amount of time spent and talking patterns, also increased. During the fall, Easy first and Only visitors spend an unexpected longer

amount of time at the exhibit with the majority spending more than one minute. Logically, this indicates that there are elements in Easy that are holding the interest of visitors, which, because the percent of visitors in the 1-4 minute category increased from fall to winter, were possibly enhanced in V3.0. It could be argued that increase of groups in the 1 to 4 minute time category were comprised of the new crop of groups that made up the increase of visits to these zones also, but because of the decrease of groups spending under 1 minute in the winter it can be concluded that the increase in time spent is due to changes in the exhibit itself.

But time alone does not tell the complete story of the quality of the interaction with the exhibit. Talk, specifically groups that engage in asking questions, making statements, and reading out-loud, is one type of learning indicator. Learning in the traditional sense, of measuring changes in factual knowledge, was not measured in this study; however, the level of talk complexity that a group engages with is a suitable rudimentary indicator of learning behavior. As expected, talk complexity increases as the amount of time at the exhibit increases, but also of interest is that the complexity increased from fall to winter. Both of these changes are also seen in visitors that visit Easy first or Only, and specifically the addition of 3 types of talking – which was absent in the fall – as the talk complexity category most engaged in by groups that visited Easy first or Only and that spent 1 to 4 minutes at the exhibit during the winter suggests that the talk complexity did not increase for Easy visits because more time was spent, but because of the exhibit itself. The percentage of visitors that spent more than 4 minutes at the exhibit that visited Easy first or Only did not change much between evaluation rounds, and since talk complexity seems to have decreased from fall to winter, it would suggest that the groups spending more than 4 minutes are not adding to the talk complexity in the winter and if anything, are talking less. So in total, the groups in the fall do not show that learning was happening when they spent between 1 and 4 minutes visiting Easy Only, but this changed in the winter were the greatest percentage of groups in those categories engaged in talk indicative of learning. This indicates that the goals of the V3.0 modifications were successful in

increasing the amount of engagement with the Easy levels as well as the quality of those interactions that result in learning behavior.

Hard

Where one of the goals of the changes made to the exhibit between V2.0 and V3.0 was to increase the engagement and visit quality in Easy, the goal for Hard was to only increase the quality of the interactions. Since it was observed in the fall that a larger number of visitors than expected went to Hard first, we didn't want to necessarily increase the total number of visits since those levels are most appropriate for a small percentage of the visitors, but coupled with the goal for Easy we wanted to increase the number of appropriate use visits. Appropriate visits are indicated by a longer amount of time spent and more complex talk since the Hard levels were more knowledge intensive and exploration based and it is anticipated that the activities presented would require more time to complete. In the fall we saw that even though there were more users visiting Hard first than Easy, the time spent in Hard was much less than the time spent in Easy. This was also true in the winter, and time spent at the exhibit for those that visited Hard first in the winter was actually less that those during the fall, indicating that our goal of increasing time in Hard was not met. This is further supported by the lower percentage of visitors engaging in any type of talk in Hard than in Easy, but specifically the talk that did occur in Hard was of lower complexity than what is occurring in Easy. Talk complexity did increase from fall to winter, but no visitors that visited Hard first engaged in 3 types of talk, which is the indicator of learning for Multi-generational groups. It has been hypothesized in this study that 2 types of talk is an indicator of learning in Peer groups, so the addition of 2 types of talking in the winter could mean that these Peer groups, who are the most appropriate audience for these levels if composed of adults, if they are in fact visiting this zone and are engaging in two types of talk, could be engaging in behavior that indicates learning. However, when groups that started at Info are added to the groups

that started at Hard and visited Hard Only, visitors engaged in 3 types of talk, but it is unclear if those Info first groups talked in the Info pages or in the Hard levels.

Nonetheless, the main goal of the three levels in Hard was to support and encourage visitors to utilize the online data, which no visitors in the fall or winter did. Some visitors did access the website, but did not create graphs or engage in the outlined activities. This indicates that either our expectation that visitors at an informal science education facility would want to interact with these data is too high, or we have yet to find the method to effectively encourage their use. We can effectively rule out the possible explanation that the visitors just don't have the knowledge or skills to understand the data online because several groups that were interviewed voluntarily provided information about their background as a scientist or having a robust scientific background who would be very capable of understanding the data if they interacted with it. One adult peer pair group in the winter was the ultimate group; both were very comfortable with interacting with data since the woman came from a family of oceanographers (one of her grandparents was featured in an another exhibit in the Visitors Center) and the man came from a family of rocket scientists and he himself was a computer engineer. During their interaction, they went to all three of the Hard levels, spending the most time in L3, and the least time in L4 and L5. When they got to L4 they started to engage in the activity as it was designed, but were noticeably confused when another screen popped up, which is how they had to view the data. They promptly closed the screen, and continued with the activity without using the data, and then only looked at the intro page for L5 before finishing their interaction with the exhibit. During the interview the man suggested that the new screen be engineered into the existing screen, which could be the barrier that needs to be addressed in the future. Possibly if the exhibit is online and people are accessing the exhibit from the comfort of their own home they might interact with the data there, but more research would have to be conducted to see if this is in fact the case. In all, users that visit Hard Only have a lower complexity of talk and spend a smaller amount

of time at the exhibit, and this trend was not majorly changed by changes in the exhibit from V2.0 to V3.0.

Easy&Hard

If used in the anticipated manner, visitors who visit levels in both Easy&Hard should potentially spend the longest amount of time at the exhibit. The exhibit was designed such that visitors could move up levels and difficulty as they finished an easier level or found the level they were in to be too easy. This trend was seen in the fall where the greatest number of visitors who visited Easy&Hard spent more than 4 minutes, but in the winter the number of visitors who spent more than 4 minutes decreased and the 1-4 minute category increased. The number of visitors in the under 1 minute category had almost no change, indicating at least that regardless of changes made to the exhibit, the majority of visitors in Easy&Hard will stay for more than 1 minute. The percent of users that visit Easy&Hard did not change from fall to winter, so the potential causes behind the decrease in time and talk complexity from fall to winter is not readily apparent. Based on the qualitative path-based total visits it is seen that the overwhelming majority of visitors that arrived at Easy&Hard after a first visit to Easy was from the winter, which at first glance could be made up of Pair Peer or Multi-generational groups. Perhaps changes in the exhibit supported this expanded use of the exhibit by these groups in the winter, but based on the shorter amount of time spent and lesser talking complexity, this may not be in fact an appropriate use that we want to continue to encourage. This suggests that in fact these groups should be encouraged to stay in the zone where they started to create a more robust experience instead of visiting multiple zones and decreasing the quality of the learning experience.

Group type and size

So now that it is determined that the exhibit caused changes in visitor behavior in Easy, we will now look at group types and sizes to see if it can be determined which group, if any alone, caused these changes seen in all combined visitors. First visits to Easy increased from fall to winter in all three group sizes as well as in Individual Adults, Peers, and Multi-generational groups; Easy was the most frequent first visit zone for Individuals, Groups of 3 or more, Individual Adults and Multi-generational groups in the winter. Likewise, where most commonly followed first to total visit path in the winter was from Easy first to Easy Only, the greatest percentage of Individuals, Groups of 3 or more, Individual Adults and Multi-generational groups in the winter followed this path as well. With so many groups contributing to the visit increase, as well as the general increase of visitors in the 1 to 4 minute categories for each group type and size, it is difficult to discern which group the changes in the exhibit have the greatest influence on. The smallest percentage of any group visiting any zone in for Individual Youth visiting Easy first, with less youth visiting during the winter than the fall, so they can be ruled out.

Peers have a story that is unique from all the other group types. They shifted from most frequently visiting Hard first in the fall to visiting Easy in the winter, but spent basically the same amount of time at the exhibit in the fall and the winter, which initially suggests that they will spend the same amount of time regardless of where they visit first. However, as mentioned previously, adult Peer groups are probably the most appropriate audience for the Hard levels, so it could be that they are equally engaged in the material and activities in both zones. Another factor in this puzzle is the role of a first visit to Info, which was followed by the highest percentage of Peers in the winter, and could be potentially extending the amount of time that Peers spend because they are engaged in the Info pages for longer at the outset of their interaction. Since Info is an important first visit to Peers, the path-based total visits for Peers are not a good indicator of use because these groups are not included in the total visit paths that are from Easy or Hard only. Based on these paths alone, the majority of Peers that visit Easy first visit Easy&Hard in total, and since Peers had an increase in 2

types of talking in the winter, we should also see an increase in 2 types of talk for Easy&Hard. But, because there are no groups in the winter that visited Easy&Hard and engaged in 2 types of talk, it can be deduced that no Peer groups that went to Easy&Hard. The full story of how Peer groups use the exhibit and the most appropriate zone for their interaction is difficult to discern from this study and would need further research to accurately understand this groups use of this type of exhibit.

Multi-generational groups also used the exhibit differently in the winter than the fall. Like other groups mentioned, the greatest percentage of these family-type groups visited Easy first and Only and spent 1 to 4 minutes at the exhibit in the winter. Based on this, we would anticipate and actually do see an increase in 3 types of talking in these groups, indicating that changes in the exhibit were effective in enhancing the interaction with the exhibit. In the fall, there were several adults in Multi-generational groups that were overhead telling the youth that the exhibit was not something they should use because there was too much reading or the information was "over their heads", but this was not observed in the winter. This indicates that adults saw the exhibit as an educational tool that was above a child's understanding and knowledge level in the fall, but in the winter perceived it to be more of a scaffolding tool, as evidenced by the increase in talking and engagement in talk that is indicative of learning. Possibly the changes in the introductory text to guide these groups to the appropriate zone was the most effective change made, but this finding also indicates that the structure and design of the Easy levels are appropriate to support family learning opportunities, and should be maintained and possibly enhanced in the future.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Methodological Qualifications

Methodological Qualifier A: Cannot make claims about gender based on this data

In order to make equal comparisons between groups in the fall and winter, there needed to be no significant difference between the rounds for the target group demographic. The percent of visitors in each of the group sizes and group types were not different in the fall than in the winter as presented in the introduction to Chapter 4, but female groups decreased and mixed gender groups increased from fall to winter with the number of male only groups relatively equal in both evaluation rounds. One hypothetical explanation as to the change from a female only dominated fall to mixed gender dominated winter is that there wasn't a decrease in female individuals per se, but their role within groups changed from being an individual user in the fall, to being incorporated into a Peer or Multi-generational group in the winter. Based on the data collected of the visitor demographics, it would be possible to continue investigating this hypothesis at a later time to describe the distribution of the two genders within the mix gender groups, but elucidating changes in exhibit use patterns from fall to winter based on group genders may be impossible with this data. Both of these types of analysis are outside the scope of this thesis, which is why use patterns by group sizes and types were focused on.

Methodological Qualifier B: Some groups started as one type or size and ended as another

One caveat to this study is the fluid nature of the social groups over the course of a group's interaction with the exhibit. The group size and type was determined

based on all the individuals that interacted with each other or the exhibit during one interaction and included any individuals who joined or left the interaction during that time. An example of this is that one group is labeled as a Pair may have in fact been an Individual for the majority of the time with one other come and look over their shoulder briefly, or another larger group could have two main individuals interacting with the exhibit and others joining and leaving without touching the exhibit or talking with the Pair interacting with the exhibit. So it is important to note that even though we found some strong patterns in the Peer and Multi-generational groups, the difficulty in identifying commonalities in visit, time, and talk patterns in Pairs and Groups of 3 or more could be related to the fact that the majority of the interaction with the exhibit was not actually occurring in that group size. This observation is supported by Dierking's findings that family interactions occur on a continuum, where some split up to interact with exhibits and then reconnect about what they saw later, to other families moving as one unit from exhibit to exhibit (Falk & Dierking, 2000).

Methodological Qualifier C: Legitimate Peripheral Participation of Adults

At first glance, it may seem that any visitor that is not physically interacting with the exhibit or socially interacting with their social group are not engaging in the interaction in a meaningful way. It was observed in many groups that an adult would join the group once the interaction began and stand behind the individuals sitting down and physically interacting with the exhibit. Some of these adults might engage in talk with the others, but many just watched over the shoulders of others. Many researchers have seen children engage in this behavior, where they are removed from the physical interaction occurring, but are intently observing the behaviors and actions of others as a model of the correct method of interaction. Legitimate peripheral participation allows the observer to learn by example therefore, and where adults may not need to learn how to interact with a touch screen monitor, they are potentially learning new information as the watch others interaction with the exhibit.

Methodological Qualifier D: Unknown impact of visiting Info pages on visitor use or learning

The Info pages were included in the computer component of the exhibit to provide background and "big picture" information of the data being presented in the exhibit. Two of these pages, the Estuary and LOBO pages, were linked from the first Intro page, and the rest were accessible from the Help (V2.0) or More Info (V3.0) buttons that was part of the side navigation bar buttons. The information on these pages was identical to the information on the posters that were in the same location as the computer, but was included after observations that visitors on the computer did not refer to the posters for additional information. Though not specifically analyzed, the majority of visitors who visited these pages with a goal (as opposed to a child who just happened upon the pages after randomly touching the screen) arrived there from that first Intro slide; few to no visitors used the Help/More Info button to find the answer to a question. We see that a good number of Peer groups, which is the group type that spends the greatest amount of time at the exhibit, visit the Info pages first, which could lead to the generalization that a first visit to Info increases the time spent at the exhibit. However, this cannot be proven to be a direct cause and effect due to other factors, such as the knowledge and skill level, motivations, or social interactions in adult peer groups. We saw that a small percentage of users who visited Info first contributed to each of the total visit groups, so the impact, if any, of visiting Info first could be diluted within all the total visit zones. More research needs to be completed to understand the benefits, if any, of visiting these pages first and if the pages should just be incorporated into the Intro pages, removing that extra step of clicking on a link.

Conclusions

Conclusion A: Together as a unit, amount of time, levels visited, and talking describe types of interaction at the exhibit

The quality of an interaction with the exhibit is best described using all three user behaviors: time, visits, and talk. Individually, these use types only provide a snap-shot of a visitor's interaction with the exhibit, and using all three provides a much more robust story. Of particular interest is the use of talk at the exhibit, primarily because of the talk complexity that was previously found to be indicative of learning, we can identify where learning might be happening. For Individuals, since they do not engage in talk, there are no outward signs or indicators of learning so we are unable to identify if they are they are learning at the exhibit and if so, what activities are supporting learning in this group. Time alone should not be used as an indicator, especially with Individual Youth who are prone to randomly touch buttons and not actually engage in the activities, since it does not tell you anything about what happened in that time span. Where users visited within the exhibit coupled with the amount of time spent is more telling, but again we can't understand the whole story of why visitors spent longer or shorter amounts of time when visiting certain places in the exhibit. Utilizing all three user behaviors is optimal since we are then able to see the difference between exhibit levels, for example Easy Only or Easy&Hard in this project, where visitors tend to spend a longer amount of time at both, but there are more signs of learning in Easy Only and less signs of learning in Easy&Hard. This allows the exhibit development team to understand areas or activities in the exhibit that need improvement.

Conclusion B: Visitors are interested in interacting with learning tool (exhibit), but not with the data itself

Without any precedent or research base, the unique exhibit created here was a test of the adaptation of the various design theories that we hypothesized would result in the type of use we anticipated. Because of this lack of precedent of methods to engage a general audience in exploring real-time and archived data, our goal was to

create and understand computer-based activities and environments that supported this type of use. Where we succeeded was that this exhibit, as a tool, has created meaning for the public to interact with data. In the Easy levels, visitors were presented with closed-answer type activities that interpreted monthly averaged graphs of river discharge, rainfall, and estuary salinity. These activities resulted in a longer time spent at the exhibit as well as an increased rate of engaging in talk that indicates learning is happening, which shows a strong visitor interest, mostly by non-individual groups, in these activities. Where visitor use of the Easy levels suggests that these activities align with visitor interests and motivations, which in Peer and Multi-generational groups are most likely to fulfill a general curiosity or an interest to teach others, this support of visitor interests is not seen in the Hard levels. The activities in the Hard levels are exploratory based and more open-ended, and for the two types of activities presented we do not see a "without-tool" interaction with the real-time data, like we see in other user groups such as fishermen and boaters. The changes made from V2.0 to V3.0 primarily focused on the Hard levels in an effort align with visitor interests by decreasing the less structured data exploration activities seen in Levels 4 and 5. There was a minimal, non-significant shift in visitor use in these levels from V2.0 to V3.0, suggesting two possibilities: we have yet to discover the activity that aligns with visitor interests so that they interact with the real-time data, or a science center is not an appropriate venue for the public to interact with real-time data. Regardless of the reason, the key message from this research is that people have to have a legitimate reason and real-world application for these datasets in order to engage with it. The Easy levels, as mentioned previously, supplied those reasons through meeting the social goals of visitors, and more development and research is necessary to create an activity or environment that engages the general public in interacting with the real-time and archived datasets.

Conclusion C: Interactive, input-based activities support behavior that indicates learning whereas passive communication activities do not in most groups

The differences in visitor use of the Easy and Hard levels have been outlined in the previous conclusion from the perspective of testing exhibit design hypotheses, but in this conclusion the effectiveness of the two types of activities are examined. In the Easy levels of this exhibit, the programming of the activities respond to a user's input to indicate the correctness of the answer and provide any necessary supplemental information, thus a true interactive-type activity where information transmission is two ways, from the computer to the user and from the user to the computer. Conversely, the activities in the Hard levels do not respond to specific inputs, and even though correct answers and explanations are presented, the information transmission is only one way, from computer to user, and therefore a more passive communication method. These are not truly interactive activities, like the ones in the Easy levels, because even though visitors touch buttons, they are only navigation buttons and not related to responding to an answer input. Because of this lack of response in these activities, the responsibility in now on the user to, either by themselves or with their social group, examine their knowledge and reflect on their understanding of the concepts being presented in the activities. This study found that these more passive, one-way communication activities are not as effective in engaging visitors in a science center to display signs of learning as much as the truly interactive activities are. Again, going back to visitor interests and motivations, perhaps the relatively simple information presented in the Easy levels, the difference in salinity between the estuary and the ocean and the seasonal relationship between monthly-averaged rainfall and estuary salinity, is more aligned with visitors' interest than the more complex information in the Hard levels. However, this more complex information, about inter-annual and daily variation and the impact of tides, we suspect is accessible to the general public but we have yet to find the optimal activity to support the behaviors that are signs of learning. Because of this suspicion that it is not the data content but the method it is presented that is the limiting factor, this cycles back to the discussion of the types of activities presented. In a formal classroom, where evaluation of one's own knowledge is expected, the passive, one-way communication activities may be effective, but in an

informal education setting, such as a science center, assuming that the majority of visitors will engage in this level of effort at an exhibit may be not be appropriate. This is not saying that no visitors will engage in learning, because we observed that some did in fact show signs of learning, but these visitors are very much in the minority. Many organizations now present web-based education or outreach products as a static informational page, which is more appropriate for home-based free-choice learning where the user can utilize that page as a reference, but, as seen in this study, these static informational pages are not an effective means of educational communication in museums, aquariums, or science centers.

Conclusion D: Exhibit fits and performs within family friendly exhibit goals

Reflecting back to the introduction, previous work by Borun et al. (1998) had described the key characteristics of a family friendly exhibit. These include: multi-sided; allows for multiple users; accessible by both adults and children; allows for multiple learning outcomes; accessible by various learning styles and knowledge levels; easily understood text; and information is relevant to previous experiences and information learned. Although not multi-sided, the exhibit developed for this project fits all of the other attributes.

Because the screen of the computer is relatively small (17" screen), most groups had only two people at a time directly interacting with physically touching the screen. However, groups of up to six people total were observed engaging with the exhibit, with two people sitting down in direct contact with the screen and others either sitting or standing while participating from the periphery. These peripheral group members varied in behaviors, some looking over shoulders at the exhibit, some verbally engaged with those physically engaged with the exhibit, and some seemed to just be standing there, waiting for the others to move on to the next exhibit. As mentioned in the methodological qualifiers, most of these peripheral group members were adults and may be processing the information in the exhibit differently than if they were the ones in charge of physically maneuvering through the exhibit.

The goal-based scenario design that was implemented allowed very much for the attainment of multiple learning outcomes. Individual adults have different learning outcomes than an adult with a youth, so allowing the visitor to choose what activity or level of difficulty they want to engage with is necessary. Even within a level, especially the Easy levels, where a youth may be building on their skills to understand graphs, adults, in helping those youth, may learn new information about the salinity or estuaries in general. No definite learning outcomes were established at the beginning of the project since we anticipated that there would be a wide range depending on previous knowledge and skills, and keeping this in mind during the design and development process was extremely helpful.

The attributes of being accessible by children and adults, accessible by a range of knowledge and skill levels, and including easy to read text all focus around the same concept. Because of the wide range of visitors at the science center, the exhibit was not designed for one specific type of group or visitor, even though some visitors thought it was more for children and others thought it would be too difficult for children. Regardless, both youth, some of whom had not been taught about graphs yet in school, and adults, some of whom were ocean scientists themselves, enjoyed the exhibit. One issue that did come up during this research was the use of scientific jargon. Most jargon was removed or any potential jargon, like river discharge, was defined as it was used. However, the unit of salinity used was Practical Salinity Units (PSU) which was a source of confusion for many visitors even after it was explained, and will be replaced by Parts Per Thousand (ppt), a more familiar unit of measure, in the future. More discussion about this is below in Recommendations section.

Finally, many efforts were made to link the information to previous knowledge and experiences. No front-end assessments were made to determine what this in fact was in the visitors at the science center, but we did know that many of them were from the Pacific Northwest and had a personal connection to the seasonal rainfall that occurs in this region. In interviews, even people from Colorado, Ohio, and Virginia made a personal connection to the rainfall that occurs in Oregon because they do not

have the same rain patterns in their home state. For more complex water quality variables, a front-end analysis should be conducted to understand how to make that connection.

Conclusion E: Math in a graphical format is family and science center friendly

Even though the concepts presented in the exhibit are scientific in nature, they are actually presented in a mathematical format. In order to read and interpret graphs, math skills, as basic as reading numbers and knowing the relationships between them, are needed. In the field of math, time series line graphs of one or two variables are most likely on the lower end of the complexity spectrum, but an introduction to this type of math in a science center now is necessary as a bridge to more complicated types of math in a science center in the future. Previous studies have found shown that visitors in museums are afraid of math activities since when presented with activities that explicitly have a term related to math in the title, visitors are least likely to engage with the activity (Rowe, pers. com. May 28, 2009). In contrast, this project engaged visitors in a math related activity because it is cloaked in science with no reference to math, but that does not allow visitors to reflect on their alternate conceptions of or attitudes towards math, letting them walk away not knowing that they just were involved with math. More concrete descriptions (i.e., equations) of the relationships presented in the graphs and discussed in the exhibit would probably not be an effective hook like the graphs since equations *look* like math, whereas graphs do not necessary get labeled as math as readily. However, since they both describe the same relationships, this is a point where classroom teachers could expand upon the graphical representations and introduce the equations that support these relationships. Back in the science center however, using time series line graphs, if presented in an entertaining manner like in V3.0 with all the necessary axes labels and legends presented in a consistent fashion, is accessible by all ages and is a very appropriate method to introduce math concepts in a non-intimidating way.

Emergent Questions and Future Research

Question A: Which better describes how visitors move through the exhibit, total visit paths or total visit destinations?

As described in the introduction to Chapter 4, the total visits within the exhibit are presented in two ways, as destination-based or path-based. Since this is a novel type of analysis, the importance and utility of one type of total visit over another is not known. Destination-based visits allow us to understand how many users are visiting one zone of the exhibit regardless of their first visit zone, and is an insight as where the most popularly visited areas are in the exhibit. Because of the ease of coding and categorizing visitors into one of the four total visit zones that is afforded by destination-based total visits, this also lends itself well to quantitative analyses to make comparisons between groups. Path-based total visits, on the other hand, helps us understand the most common sequence of visits taken from the first zone visited to the total zones visited. Because there are so many combinations of first to total visit zones (nine paths that originate from the Home to Intro entry point), quantitative analysis is not as appropriate because of the small sample sizes that may occur. So they each provide us with unique views of how the exhibit is used, but based on this study, it is not conclusive if one method is more informative over the other, never mind declaring if one is more useful over the other. Both methods were useful in describing trends in this thesis, but further research is necessary in order to understand the most effective methods of analysis of this type in the future.

Question B: What talk complexity is indicative of Peer groups learning?

Previous work by Borun, et al. (1998) showed that an indicator of learning in family groups is the engagement in asking questions, reading out-loud from the exhibit text, and making statements about the exhibit. These findings were utilized in this

study to identify where in the exhibit groups exhibited signs of learning, and were useful in describing the patterns of potential learning in Multi-generational groups. However, where we saw an increase in these three types of talk in Multi-generational groups, we saw a decrease in three types of talk in Peer groups with an increase in two types of talk. Looking back at the dialogues that these two groups engaged with, one major difference between them is the use and role of questions within those groups. Adults in Multi-generational groups ask the youth in the group questions to support that youth's learning, and youths ask adults questions to understand and/or clarify the information in the exhibit or for the adult to evaluate their performance. In Peer groups, which were primarily composed of adults, questions were used to clarify information presented in the exhibit only, and therefore if the exhibit is clear in its message and instructions, Peer groups may not have a need to engage in all three types of talk to learn. More research is necessary in this since this finding is only a preliminary observation and needs more evidence to back up the claim.

Question C: Is the topic of real-time data appropriate for Individual Youth?

Real-time data can be an abstract concept because the user of the data visualization typically does not ever see the instrument collecting the data or the environment that the data is being collected from, and especially data from the ocean, changes in many variables, such as salinity, cannot be seen by the naked eye. This can pose a potential challenge in explaining these data to the general public, but particularly with Individual Youth, or any individuals that are High school aged or younger. We saw that youth that interacted with the exhibit with an adult as part of a Multi-generational group spent longer amounts of time in knowledge and skill appropriate Easy levels, whereas youth alone did not have a consistent use pattern. Of the limited number of youth that started at Easy levels, they spent longer amounts of time at the exhibit, but it was observed of many youth, particularly those that were not of an age where they would be a proficient reader, that they would touch the screen and buttons to make the screen change and not be engaged in the activities. Because

all of the activities are based on reading text, it is unknown if Individual Youth are an appropriate audience to target with this exhibit, and if so, what type of activity would support an anticipated use pattern. One potential avenue is to develop a non-text based game, but the challenge in that is first how to make graphs non-text based and second is how to direct youth to using that activity. From another perspective, one potential outcome of a youth using this exhibit alone, especially the youngest ones, is that they are interacting with a touch screen which is potentially supporting their understanding of how to interact with technology, and perhaps this learning outcome is enough for this group. More research can be done to more fully examine this issue.

Question D: What is an appropriate average time spent for an interactive computer-based exhibit?

The average amount of time spent at exhibits in general is 30 to 60 seconds. Research has shown that interaction with an interactive exhibit extends that amount of time, but there is no definitive average or range for these types of exhibits. The first round of evaluation observing use of V2.0 resulted in a visitor distribution across time that we might expect for a typical exhibit with the greatest percentage of visitors spending less than one minute. This highest percentage then shifted to the 1 to 4 minute category for the visitors using V3.0, which is what is expected for an interactive exhibit and was reflected in an increase in groups in all four group types for this time category. Moving forward with this project, and with other computer-based exhibit projects, is using this 1 to 4 minute category as a benchmark of where the greatest percentage of visitors should be falling. One of the conclusions stated previously is that time, where visited, and talk should be used together to determine the quality of the engagement with the exhibit, but using time as a preliminary indicator of use may prove to be acceptable in the prototyping process to determine the effectiveness of one specific activity.

Where the one minute mark was based on previous research, the four minute mark was based on preliminary observations of this exhibit to target users who went

through an entire or majority of a level. This four minute mark may not be able to be widely applied to other exhibits since it is not known if this is a function of the design of the exhibit that inherently kept the visitors at the exhibit that long because of the amount of time it takes to get through the animations, or if it is directly related to the social interactions and use of the exhibit. We did not have any assumptions from the outset of how much time it would take visitors to get through any one of the levels since the range of time varies with the knowledge and skills that the user has. These time categories are relatively broad, so further research is needed to understand if this four minute mark is the best description of time spent or just a construct of this project, and also a better understanding of the visitor patterns within each time category. Because of the small sample size of this study, these broad categories were necessary, but research efforts with a larger sample size may possibly be able to examine visitor use patterns in smaller, one minute increments within that 1 to 4 minute category. We did find, however, that both evaluation rounds, for V2.0 and V3.0, yielded an average time spent at the exhibit to be close to 2.5 minutes, possibly indicating that a general average or time range for interactive computer exhibits could be described after more research is conducted.

Question E: Animations as one effective educational means of one-way communication?

As mentioned in the conclusions, passive means of communication in a computer-based exhibit does not support learning indicative behavior in most groups. One method of one-way information transmission, however, that may prove to be effective is the use of animations to highlight the relationship of two or more variables or concepts. Utilizing an active visual aide can help orient the user to certain areas or patterns to focus on and provide a focus in cognition on the relationship itself instead of mentally creating and holding a visualization for themselves on top of that relationship assessment. More research should look into this method of communication, as used in Level 3 of V3.0 in this exhibit to animate the relationship

of estuary salinity and rain storms or tides, to identify if it alone supports the signs of learning seen in talk, or if these animations need to be used in conjunction with some sort of input assessment that encourages the visitors to engage in all three types of talk.

Question F: If the exploratory-based activities in Hard are not appropriate for the science center, are they appropriate for use if the exhibit was hosted on the internet?

One conclusion presented is that a science center is not an appropriate venue for the exploratory-based activities in the Hard levels, which can be due to many different reasons ranging from fulfilling the social group's collective needs to an overeager design team. Regardless of the reason, the question then posed is if there is an appropriate venue for these activities, or if they are completely beyond the general public's interest and motivations. One venue that should be attempted is hosting the exhibit on the internet and track usage of the exhibit from there. The entire quality of the interaction with the exhibit will not be known since talk will not be able to be tracked, but possibly the comforts of home may allow for longer interactions with the exhibit and engagement with the activities in the Hard levels. Possibly some of the physical and social constraints experienced by groups in the science center would be removed when at home and allow for the types of interactions that we anticipate seeing in these levels. Hosting the exhibit online would also not only allow the general public access from home, but also teachers could utilize it as a teaching tool in classrooms. Right now the exhibit is very much focused on the Pacific Northwest's seasonal rain patterns, but this could easily altered for a more generic exhibit version that is more broadly applied to estuaries in general. Teachers have left comments at the science center indicating an interest in using this in their classrooms, so then the question is not if teachers are interested in using the exhibit but how to modify the activities to better fit classroom goals.

The challenge in hosting the exhibit online is the process of marketing and promoting the exhibit. In a science center, there is a defined number of exhibits that a

visitor can engage with, but online there are an infinite number of websites and resources, so the difficultly is in targeting a broad audience. Narrowcasting to defined groups, the users of the exhibit at the science center and teachers in the Pacific Northwest is one avenue. With this method there is potential for a broader distribution of users if visitors or school children show the exhibit online to friends and family. Broadcasting methods could include utilizing established websites dedicated to social networking, like Facebook or Twitter, or marine science extension, like Sea Grant, to reach a broader audience. Another potential broadcasting method is to target the captive audience on airplanes by developing more of a game environment to be included in the seat-back screens on some commercial airplanes, which would probably require a greater effort due to the necessary cooperation with airline companies. Which method, narrowcasting or broadcasting, is more effective is not known, and would probably depend on the goals of the product that is being promoted.

Question G: Is interaction with real-time data necessary, or is use of archived data appropriate?

The data used in all the activities, except for that in Level 5 that encouraged users to explore the online data, was archived data. Even though the overall project goal was to engage the general public in using real-time data, the exhibit goal was to support this interaction by providing the background information and skills necessary for this ultimate interaction. This was accomplished by using archived data that was presented in formats of varying complexity to provide a clear story of how to interpret the more complex real-time graphs. We saw signs of learning in the groups that interacted with the archived data, but only a handful of groups accessed the online data, and of those none engaged in the graphing activities. In following the theme of several of the previous questions, it is not known if the actual activities resulted in this lack of engagement, or if it is the data itself. Possibly the context provided by the exhibit using the archived data created this construct that makes it seem like visitors are not interested in interacting with the online data when in fact the design of the

exhibit does not sufficiently provide a context and applied reason to investigate the real-time data. More research is necessary to examine if there is a difference between visitor use of archived and real-time data, and if so, what methods are needed to successfully address the significance of both types of data.

Question H: How to apply findings here about salinity to more complex variables (such as nitrate, dissolved oxygen, and fluorescence)?

This question pertains most directly to the future research to be accomplished in efforts to make the exhibit a comprehensive story about estuary dynamics. Now that we have a basic understanding of the types of activities that are engaging to science center visitors, how can these activities be modified and incorporated into the exhibit to explain more complex relationships between abstract variables that visitors may not have a personal connection to. The current salinity module utilizes the personal connection with seasonal rainfall in the Pacific Northwest to tell the story of salinity; nitrate, dissolved oxygen, and fluorescence may not have such an easily accessible personal connection, which may be a source of challenge in the future development of the exhibit. Also, these three variables have a greater number of more complex drivers that result in changes, some of which are not completely understood or described by the scientific community, and presenting some uncertainty from the scientific community may be challenging to navigate so that users do not walk away with a misconception of the data or the scientific community. All of these areas of concern need to be addressed as development of the exhibit moves forward.

Recommendations

Recommendation: Work with a large design and development team

- Include a broad range of diverse experts

  - Expert knowledge that is needed: information about the data collection tool and data processing (any Quality Control/Quality Assurance methods), data interpretation, understanding of oceanographic processes, exhibit design, science interpretation for a general audience, exhibit evaluation, skills in using computer software appropriate for developing an exhibit
  - Each expert group provides information relevant to their field as necessary in a collaborative effort to design and provide feedback
- Have one keystone player that efficiently works with each expert group independently
  - This project started with a handful of brainstorming meetings that included parts or all of the expert groups.
  - The keystone player, in this case the author who developed and evaluated the exhibit, is able to compile and oversee the implementation of these design ideas
  - During the development process, the keystone player meets separately with each group to share progress made or solicit feedback, with only a few all stakeholder meetings necessary, making the process more efficient
- Science and technical experts are extremely necessary to fact check the interpretation in the exhibit to preserve scientific integrity
- Very helpful to define roles of each expert or expert group early on to ensure accountability so that tasks are completed and deadlines are met
- The process of creating an exhibit also allows for a learning opportunity by the stakeholder groups involved of concepts and skills that are not in their field
  - Example: scientists could learn or start to appreciate effective methods of communication outside of the science community; exhibit or education specialists may learn more ocean-related concepts.

Recommendation: Know and work with your audience

- Personally connect visitors to concepts
  - Use front-end analysis (through surveys, interviews, etc.) if necessary to understand baseline knowledge or skills
  - Use information, either known or from the front-end analysis, that is generally known by all visitors as a starting reference point for the story
  - The utilization of a mascot, avatar, spokesperson, etc. in the exhibit that the visitors interact with personalizes otherwise faceless concepts, making it more engaging
- Make concepts relevant to the visitors
  - Visitors generally will not engage with activities that has no direct application to their lives
  - Along with having a personal connection, visitors generally have a specific reason why they are interacting with the exhibit – in this study it ranged from one gentleman who kept pressing the "Touch here to continue" button because it told him to another visitor who was going to use the dataset for his job.
- Don't design and develop an exhibit purely based on assumptions about the audience
  - The visitors should have the final say about the design by testing and evaluating design assumptions
- The exhibit stakeholders include the funders, the design and development working group, and the audience
  - All the front-end stakeholder groups, the funders and the working group, have different goals for the exhibit and their visions of the end-product may not be aligned with the most effective means of communicating to the general public and/or goals of the intended audience
  - User-centered design of the intended audience needs to be used in order to accomplish all stakeholder goals
- Evaluate visitor use of the exhibit and make changes as necessary

- The evaluator acts like an advocate for the visitor – reporting back to the other stakeholder groups the effectiveness of the design and appropriateness of the message and concepts
- Most likely will not get the design perfect on the first try, need to work with the visitors to understand the challenges or points of confusion they face while using the exhibit

Recommendation: Avoid scientific jargon

- Remove as much jargon as possible
  - Our team was unsure of certain words (indicator, discharge, data is/data are), and made a judgment call to either remove it or test visitor comprehension during the evaluation
  - When removing a jargon word, work with the stakeholders to come up with appropriate alternative words that can be substituted so that the message is clear and concise
  - An in-text definition may result in too much text on that page, so a hyperlinked button to another page for a more in-depth explanation may be more appropriate
- Scientists and technical experts also range in their understanding of how to effectively explain concepts to the public
  - An up-front understanding and reminders during the development that they have a way of speaking and communicating within their community that is different than how the general public communicates may be helpful
- New types of units of measure is a source of confusion for visitors
  - Practical Salinity Units (PSU) was used in all three versions of this exhibit as the unit of measure for salinity

- It was decided that a new type of unit (PSU) would be easier to understand by the public, in whom it has been instilled to have units of measure, than the correct label of no unit at all
- Scientists in this project said that using parts per thousand (ppt) is acceptable for the science center even though it is not used in the science community any more

Recommendation: Build a cohesive, easy to understand story

- Cohesive in that the steps made to understand the concepts are logical, in small enough increments, and flow from one idea to another
  - The levels of this exhibit sequenced from how to read a graph, the seasonal relationship between rainfall and estuary salinity, how to interpret more complex salinity graphs, and applying graph interpretation knowledge on archived data graphs in a structured then unstructured activity
  - Within each level, only the supporting information necessary for visitor comprehension was presented, other extraneous information was skipped or glossed over
- Story includes recurring themes and messages that are referred back to and tie the entire exhibit together
  - The overall theme of the exhibit is factors that change the salinity in the estuary, and these factors were outlined as necessary in each level, and concepts mentioned previously in a level were sometimes mentioned again as a reminder or as part of an explanation
- Define new characters (water quality variables in this case) as they enter the story for complete understanding by the visitors
- Use more narrative communication approach to mask paradigmatic steps

- The science community uses a paradigmatic way of communicating where the reasoning or explanation is laid out in a logical, step-wise manner (ex: a mathematical proof)
- To a general audience, this method of communication is not effective, due to several factors which may include lack of understanding on the part of the visitor or the dry, low entertainment value of this method
- Narrative communication (ex: stories) is more effective for the public to understand and engage with
- This exhibit utilized both methods of communication by cloaking the paradigmatic presentation of the steps necessary to understanding graphs in narrative-type format

Recommendation: Activities and exhibit are not just hands-on, but "Minds-on"

- Design must force visitors to confront knowledge actively, it cannot be assumed that visitors will do it on their own if just presented with the information
  - Visitors are not like a sponge that soak up any information presented to them, has to be actively incorporated into their web of previous knowledge, which can be difficult particularly in regards to misconceptions
  - In this exhibit, the most effective method that resulted in the highest frequency of observable signs of learning was input-based question/answer sequences where the visitor had to input an answer to continue the activity
  - Conversely, we saw that passive (no input) question/answer sequences resulted in a low frequency of observable learning indicators
  - The exhibit design must support learning and application of the concepts along the way, not just static or passive presentation of materials with a quiz at the end
  - Utilize small design elements visitors enjoy interacting with (i.e. pressing buttons, animations, challenge their knowledge or skills) that will encourage a robust engagement

- Use concepts from goal-based scenarios and problem-based learning, both of which are used extensively in training simulators
  - Goal-based scenarios allow the learner or trainee to choose and pursue which goal they want to attain by the end of the learning session (i.e., learn how to land a plane)
  - Problem-based learning is centered on the effects of the decisions made by a learner or trainee when faced with a problem (i.e., you have a patient with these symptoms, what do you do?)
  - Both provide a real-world application of knowledge that are meaningful to the user
- Ask relevant questions that support goals related to increasing proficiency in interpreting graphs (a visitor's sense making) and a visitor's personal connection to the data and the ocean

GLOSSARY

Computer exhibit versions:

V2.0- Version 2 of the exhibit, evaluated during Fall 2008

V3.0- Version 3 of the exhibit, evaluated during Winter 2009

Destination-based- A type of total visit: purely based on the percentage of groups that end up in that total visit zone, regardless of where their first visit was.

Evaluation rounds:

Fall 2008: evaluation of exhibit V2.0

Winter 2009: evaluation of exhibit V3.0

First Visit- the first zone visited after the Home and Intro pages

Done- a first visit zone, the visitor only visited the Home and Intro pages

Easy- a first visit zone, the user visited L1 or L2 first

Hard- a first visit zone, the user visited L3, L4, or L5 first

Info- first visit zone, includes the Estuary and LOBO informational pages

Group size: visitor group demographic that is dependent on the number of people in the group

Individual- a group size category: consisting of one person

Pair- a group size category: consisting of two people

Group of 3 or more- a group size category: consisting of 3 or more people

Group type: visitor group demographic that is dependent on the social structure of the group

Individual Youth- a group type category: consisting of one person that looks to be in high school or younger

Individual Adult- a group type category: consisting of one person that looks to be of college age or older

Peer group- a group type category: consisting of at least two people that look to be of similar age

Multi-generational group- a group type category: consisting of at least two people that look to be in two different generations (i.e. a family-type group)

Informational pages:

Est- the Estuary page, one of the background informational pages accessed from the first Intro page

LOBO- the LOBO page, one of the background informational pages accessed from the first Intro page

Learning Levels- Levels 1-5 in the exhibit

L1- Level 1 of the exhibit, Learn how to build a graph

L2- Level 2 of the exhibit, How to interpret rainfall, discharge, and salinity graphs

L3- Level 3 of the exhibit, How to read or interpret real-time data graphs

L4- Level 4 of the exhibit, Investigating rhythms using real-time data or Rainfall and salinity match-up challenge

L5- Level 5 of the exhibit, Discover Yaquina Bay's salinity story in real-time data

LOBO instrument- the Land/Ocean Biogeochemical Observatory system, specifically designed and developed by WET Labs to collect long-term water quality data in an estuary

Path-based- a type of total visit: based on how groups navigated from one zone to another and determines the most common path taken by groups.

Talk complexity- The number of different types of talk that one group engages in; ranges from none to three.

Talk type- visitor talking was categorized into reading out-loud, asking a question, making a statement, and any type of talk

Total visit- the total zones visited by a group, Info is not included

Not a Learning Level- a total visit zone, did not visit any Learning Levels

Easy Only- a total visit zone, visited only L1 or L2

Hard Only- a total visit zone, visited only L3, L4, or L5

Easy&Hard- a total visit zone, visited at least one level in Easy and one level in Hard

Zones- the larger categories that the exhibit levels and pages are grouped into: see categories under **first visits** and **total visits**

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