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Emerging Technologies: Bringing the North Atlantic Right Whale to Life at the New England Aquarium

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Abstract

There are approximately 500 North Atlantic right whales alive today, and human actions continue to threaten their population. The goal of our project was to identify and analyze emerging technologies that could be used at the New England Aquarium to educate the public on the dangers facing the North Atlantic right whale. We researched how five emerging technologies could be implemented at the New England Aquarium through an analysis of nine example exhibit ideas. These exhibit ideas were evaluated on their ability to attract, hold the attention of, and communicate a message to visitors. We concluded that virtual reality, augmented reality, mixed reality, touch screens, and projection mapping are viable mediums for educating visitors in an aquarium setting in place of live animals.

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Executive Summary

Currently, the North Atlantic right whale is listed as endangered, with an estimated 500 whales remaining worldwide (Pettis & Hamilton, 2014). Unfortunately, ship strikes and fishing line entanglements continue to unintentionally harm North Atlantic right whales. Many efforts have been made to help protect these whales, but without public support, changes will not be made. Museums and aquariums offer an informal learning setting to inform visitors about the dire situation North Atlantic right whales face, in an effort to inspire visitors to take action.

The New England Aquarium (NEAq) of Boston, Massachusetts has the longest running research program dedicated to the North Atlantic right whale. Despite the NEAq's conservation efforts, the Aquarium facility itself lacks an exhibit dedicated to educating the public about North Atlantic right whales. At 45-60 feet long, these whales are too large to be humanely contained to an aquarium tank. The NEAq would like to utilize technology to bring the North Atlantic right whale "to life" in the Aquarium. The goal of a North Atlantic right whale exhibit at the NEAq would be to educate the public about right whales, and encourage visitors to join in the conservation efforts.

Goal and Objectives

The goal of our project was to identify and analyze emerging technologies that have the potential to be used at the New England Aquarium to educate the public on the dangers facing the North Atlantic right whale. To further develop information regarding emerging technology in an aquarium environment, we accomplished three research objectives:

1. Identified characteristics of exhibits that attract, hold the attention of, and communicate the intended message to visitors

2. Developed exhibit design criteria based upon identified characteristics

3. Used the criteria to analyze emerging technologies that could be implemented in a right whale exhibit

Methodology

For this project, we worked to identify and analyze emerging technologies that have the potential to be used in an aquarium exhibit. These technologies are:

- Virtual Reality
- Augmented Reality
- Mixed Reality
- Touch Screens
- Projection Mapping

To determine whether these technologies could be used for an exhibit involving the North Atlantic right whale, we started with an investigation of what makes an effective museum exhibit. This investigation required examination of three components that must be considered, including: attracting power, holding power, and communicating power. Attracting power refers to an exhibit's ability to draw in visitors. Holding power refers to an exhibit's ability to maintain visitor attention. Communicating power refers to an exhibit's ability to effectively convey a message to visitors.

We generated a list of characteristics possessed by effective exhibits by conducting interviews with three NEAq employees, a whale watch employee and two employees at an additional museum. Due to time constraints, we were unable to conduct interviews with experts outside the New England area.

Based upon our background research, we then identified technologies that could be used in an aquarium exhibit. The technologies we considered were virtual reality, augmented reality, mixed reality, touch screens, and projection mapping.

Using information gathered from our conducted interviews, as well as the literature we then developed a rating system using the definitions for each characteristic.

Using the exhibit design criteria, as well as the emerging technologies we identified as potentially appropriate for an exhibit on whales, we developed several exhibit design ideas. These ideas were inspired by exhibits we learned about through our research. We also considered our goal of educating visitors about the North Atlantic right whale. These exhibit ideas were meant to provide practical applications for the technologies as we analyzed them. Using the defined characteristics and limitations, we rated each exhibit in regards to the defined characteristics and limitations.

Discussion

Through our interviews and literature review, we determined thirteen characteristics for an effective right whale exhibit at the New England Aquarium. We also categorized each characteristic into either attracting, holding, or communicating power. In addition, we included criteria related to important needs and limitations of a potential exhibit about whales in the NEAq. These are included in the following table:

Characteristic/Limitation	Definition
"Wow Factor" (Attracting Power)	An exhibit that is unique: "unusual, large, strange, or cute"
Physical Design (Attracting Power)	Possess adequate space and lighting
Interactive (Holding Power)	Encourages hands-on experience
Immersive (Holding Power)	A "deep mental involvement" in a subject
Multigenerational (Communicating Power)	Encourages interaction between age groups
Focused on Education (Communicating Power)	Focus on convey a message to visitors
Easily Navigated (Communicating Power)	Require no prior knowledge of technology
Supported by a Staff Interpreter (Communicating Power)	Encourage interaction between staff and visitors
Cost Effective (Limitations)	Price of hardware should be low
Fit Within Available Space (Limitations)	Fits within the NEAq building
Easy to Maintain (Limitations)	Require little maintenance
Accommodate Animals (Limitations)	Does not cause harm to animals in surrounding exhibits
Durability (Limitations)	Can withstand excessive use

We defined and evaluated nine exhibit ideas that integrate virtual reality, augmented reality, mixed reality, touch screens, and projection mapping. Using our criteria, we were able to determine which characteristics each exhibit possessed. If the design fit the above definition, we gave it a “+” in regards to that characteristic. If the design partially fit the definition, we gave it a “0”. Finally, if the design didn’t fit the definition, we gave it a “ - ”. The following shows how each characteristic emphasized the attracting, holding, and communicating powers based on the exhibit design:

Swim with the Whales

This “Swim with the Whale” exhibit uses virtual reality to allow visitors to “swim” with North Atlantic right whales and experience a day in their life. The exhibit would attract visitors through its “wow factor”. The holding power of this exhibit would be very strong, since would be both interactive and immersive, but it would lack characteristics that would give it a strong communicating power.

Interactive Whale Smartphone

The “Interactive Whale” augmented reality application works with the aquarium to "bring the building to life", featuring a whale skin overlaid on the skeleton that can be tapped for more information. The exhibit would attract visitors through its “wow factor”, and its interactivity would hold the visitors’ attention. The exhibit’s communicating power would be strong, since this exhibit would be multigenerational and focused on education.

Digital Whale

This augmented reality exhibit would display digital whales (and other aquatic life) in the Aquarium tanks, allowing visitors to "talk to" and learn from the animals. The attracting power of this exhibit would be strong, because it would have both “wow factor” and a suitable physical design. The holding power could be improved, since the exhibit is only partially interactive and immersive. This exhibit would also be easily navigated, and have a focus on education, indicating a strong communicating power.

Boat Simulator

The “Boat Simulator” exhibit would utilize mixed reality similar to a flight simulator, allowing visitors to experience what it would be like to captain a cargo boat or fishing vessel in North Atlantic right whale territory. The physical design of this exhibit indicates good attracting power. The holding power of this exhibit would be very strong, since it would be both interactive and immersive. Because it is only moderately multigenerational, focused on education, and easily navigated, this exhibit does not have a strong communicating power.

Life-Sized Whale

The “Life-Sized Whale” exhibit would involve constructing a life-sized North Atlantic right whale for visitors to walk in and around, with touch screen monitors displaying videos to supplement information. The “wow factor” and physical design of this exhibit would indicate a strong attracting power. The holding power of this exhibit would mostly come from its immersiveness. This exhibit would be easily navigated, but only moderately multigenerational, focused on education, and conducive to an interpreter. Therefore, the communication power would be slightly lacking.

Interactive Video

The “Interactive Video” exhibit would involve an interactive video displayed on touch screens where visitors make their own decisions and see how they impact North Atlantic right whales. The attracting power would come from its physical design, and the holding power would come from its interactiveness. Its focus on education and easy navigation would indicate good communicating power.

Swimming North Atlantic Right Whale

This “Swimming North Atlantic Right Whale” exhibit would involve projecting mapping a life-sized North Atlantic right whale to swim around the Aquarium walls. The “wow factor” and physical design of this exhibit would indicate a strong attracting power. This exhibit lacks a strong holding power, however, since it would not be interactive and would only partially be immersive. It would also lack in communicating power. This exhibit would be easily navigated, but only partially multigenerational and conducive to an interpreter.

North Atlantic Right Whale

The “North Atlantic Right Whale” exhibit would involve using projection mapping to project a healthy North Atlantic right whale, followed by a North Atlantic right whale that has been affected by ship strike or fishing line entanglement. The exhibit would have a strong attracting power due to its “wow factor” and physical design. The holding power would be lacking, since it would not be interactive and only partially immersive. The easy navigation and use of interpreter would indicate good communicating power.

“Live” Show

This exhibit would be a "live" show featuring a projection mapped whale and live human interpreter to discuss whales and answer visitor questions. The “wow factor” and physical design would indicate a strong attracting power. The holding power would derive from its immersiveness. This exhibit would have a strong communicating power, since it is focused on education, requires an interpreter, and is easily navigated.

Conclusions

Analysis of Findings

After ranking the characteristics for each exhibit, we looked for trends relating to technology as a whole. We found that exhibits utilizing emerging technology generally possess "wow factor" and promote an attractive physical design. In addition, emerging technology generally does not encourage, but still allows for, multigenerational interactions. We then looked at each of the individual types of technology, and found the following trends:

- Virtual reality effectively holds visitor's attention.
- Virtual reality does not effectively communicate to visitors
- Augmented reality requires the least amount of resources.
- Mixed reality effectively holds visitor's attention
- Mixed reality does not effectively communicate to visitors
- Projection mapping effectively attracts visitor's attention
- Projection mapping does not effectively hold visitor's attention

Limitations of our Project

We encountered several limitations over the course of our project. Despite efforts to reach staff at museum and aquarium facilities outside the New England area, we were only able to conduct interviews at regional attractions. Additionally, we were unable to conduct visitor interviews, which means that we were unable to provide a first-hand visitor opinion on the technologies presented in our report. We were, however, able to counteract this deficit of information with information provided by the NEAq regarding visitor activities and opinions. Finally, we were unable to accurately estimate cost, space and upkeep, as these would require in-depth knowledge of the NEAq, as well as exhibit design.

Recommendations for Moving Forward

We have three recommendations for moving forward. First, we recommend the NEAq continue to investigate these emerging technologies and implement them in future exhibits. Through our research, we found that emerging technologies serve as a suitable substitute when live animals are unavailable in an aquarium environment. Second, we recommend the NEAq select one of our exhibit designs and develop it further or use our ideas as inspiration for a new exhibit utilizing emerging technology. Finally, we recommend the NEAq apply the method we developed and used throughout this report, to analyze future emerging technologies. The information we provided will show the NEAq the advantages of emerging technologies to further exhibits and bring animals "to life" within the Aquarium facility that were never before possible.

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1. Introduction

Ever since the Whaling Era ended in 1935, the North Atlantic right whale has been listed as an endangered species by the International Union for Conservation of Nature (Kraus & Rolland, 2010). Today, there are only around 500 North Atlantic right whales remaining in the wild (Pettis & Hamilton, 2014). The main sources of danger to the North Atlantic right whale population are fishing gear entanglement and ship strikes (Knowlton and Kraus, 2001). A study that took place from 2007 through 2011 found that, on average, four to five right whales were killed annually due to human activities. Of these deaths, about three right whales died as a result of fishing gear entanglement and about one right whale died due to ship strikes (NOAA, 2014).

The end of the whaling era gave rise to several international treaties written to protect North Atlantic right whales, the first of which was signed in 1935 by fifteen nations including the United States. Later, in the 1940s, *The International Convention for the Regulation of Whaling* was signed (Anina, Ferguson, Helderman, Wang, 2014). Nationally, the US government has taken its own actions to help conserve the North Atlantic Right Whale. Some of its efforts include enforcing reduced ship speeds in certain areas and drawing out alternative travel routes to avoid right whales (NOAA, 2015). However, these efforts have not been successful. For example, a study measuring the effectiveness of the "10 knot speed limit" law, created in order to protect the North Atlantic right whales from ship strikes, found a "substantial" number of vessels were not in compliance with the speed limit (Silber, Adams, & Fonnesbeck, 2014). Speeding makes ship strikes with right whales much more common, because the time to avoid collision is greatly decreased. Steps have also been taken to help reduce the number of fishing line entanglements that occur, such as requiring breakaway lines that snap when a force greater than 600 pounds is applied and reducing the number of vertical lines lobstermen in North Atlantic right whale territory are allowed (Anina et al. 2014). Despite these efforts, fishing line entanglements remain a major threat to North Atlantic right whales (Anina et al. 2014).

To help remedy these ineffective legal and voluntary efforts, many organizations have attempted to educate the public about the endangerment of the North Atlantic right whales (NOAA, 2015). Successful education is intended to provide the public with valuable information, allowing them to gain a deeper understanding of and appreciation for North Atlantic right whales, which in turn will encourage the public to act on behalf of the whales. A Professor of Psychology at CSUSM, claims that "conservation [of the environment] can only be achieved by changing behavior" (Schultz, 2011). Without education to thoroughly inform the public of the dangers facing North Atlantic right whales, stronger and improved enforcement of laws may be difficult to achieve.

Institutions such as aquariums are well equipped for informing visitors about the plight of North Atlantic right whales, due to their extensive knowledge on the animals and their focus on informal education. For example, many aquariums have exhibits on whales, including Mystic Aquarium, which houses live Beluga whales, and The Natural History Museum in London, which houses a life sized Blue Whale model. However, there are very few exhibits specifically featuring the North Atlantic right whale.

The New England Aquarium (NEAq) in Boston, Massachusetts is host to the longest running right whale research program in the world. Through their research efforts, they aim to inform the public and ultimately, protect North Atlantic right whales (New England Aquarium, 2015). The NEAq has several projects dedicated to preserving the North Atlantic right whale, such as using geographic information system (GIS) technology to study how commercial fishing affects right whales (New England Aquarium, 2015a). The Aquarium also created the North Atlantic Right Whale Catalog, which contains over 200,000 photos of North Atlantic right whales and is investigating new fishing gear that would reduce entanglements (Ewing, Fortin, Espinoza, Tierney, 2013; New England Aquarium, 2015b). In addition, the NEAq has also researched developing a videogame to educate aquarium visitors about North Atlantic right whales (Anina et al. 2014) and thus far, a prototype of the game has been developed (Bryant, Bujnevicie, Petersen, Prueitt. Racine, 2015).

However, the only existing exhibit at the Aquarium about the North Atlantic right whale is a stationary whale skeleton suspended from the ceiling containing little signage. This exhibit provides limited representation of the full depth of the NEAq's efforts to protect the North Atlantic right whale population, and is not one of the principal exhibits that draws visitors in and maintains their interest. Since a live North Atlantic right whale cannot be brought into the Aquarium, there is interest in exploring opportunities to use various technologies in order to create a more compelling exhibit.

Exhibit Developer of the Montshire Museum of Science, claims that there are six characteristics of good exhibits: an exhibit must invite visitors in, be easily navigated, inspire interaction, contain accurate information, be accessible to all ages, and leave the visitor with something they can take away, such as an idea or thought (Raiselis, 2011). Two other exhibit design researchers developed a similar model, claiming that there are three categories which promote the educational and entertainment value of exhibits. These categories are physical design, interaction, and content (Mailund & Halskov, 2008). Exhibits such as *Titanic: The Artifact Exhibition* and *Dinosphere: Now You're in Their World* excel in these three categories as they allow visitors to experience a world they could not otherwise, using the theory of "spectacular design". This theory explains how museums and aquariums can use technology, as well as techniques found in theme parks or theaters, to create "awe-inspiring" exhibits (Counts, 2009).

There are many emerging technologies in use at museums around the world. For example, technology exists to re-create small scale museum artifacts in augmented reality, as well as to develop digital "animals" that can interact with and learn from each other and people in the real world, allowing them to behave much like an actual living animal would (White, Liarokapis, Darcy, Mourkoussis, Petridis & Lister, 2003). These technologies allow visitors to experience exhibits in a way never before possible- by getting a full, 360 degree view of artifacts and observing animals up close that were previously never found in museum or aquarium settings.

The goal of our project was to identify and analyze emerging technologies that have the potential to be used at the New England Aquarium to educate the public on the dangers facing the North Atlantic right whale, and captivate visitors about the wonders of the animal. To accomplish this goal, we had three primary research objectives:

1. Identify characteristics of exhibits that attract, hold the attention of, and communicate the intended message to visitors
2. Develop exhibit design criteria based upon identified characteristics
3. Analyze emerging technologies that could be implemented in a right whale exhibit using the exhibit design criteria.

Ultimately, our research provided the NEAq with a list of emerging technologies and example exhibits that utilize these technologies. By accomplishing our research objectives, we were able to determine many characteristics of popular and informative exhibits. Using these characteristics, as well as taking limitations such as cost of hardware and space available at the NEAq into consideration, we presented a matrix comparing our example exhibit ideas. This matrix will aid the NEAq in selecting an exhibit idea or technology that they could use to educate and encourage the public to act on behalf of the North Atlantic right whale.

2. Background

Through our project, we identified and analyzed emerging technologies that could be used in an aquarium exhibit that brings the right whale to life and educates the public on the dangers facing the North Atlantic right whale. In this chapter, we examine four major topics. First, we discuss the research done on North Atlantic right whales and the dangers they face. Second, we describe actions that have been taken to protect North Atlantic right whales. Third, we explain the importance of informal education as a means for the public to further learn about topics of interest to them. Finally, we showcase different technologies that could be used in the New England Aquarium (NEAq).

2.1. The Endangerment of the North Atlantic Right Whale

With a length of 45 to 60 feet, the North Atlantic right whale is one of the largest whales on earth (Cupka & Murphy, 2005). They are very slow animals, traveling at an average speed of just six miles per hour (Defenders of Wildlife, 2015). Most of their time is spent not far from the Atlantic coast (Smithsonian National Museum of Natural History). Currently, the North Atlantic right whale is listed as endangered. Humans have been a major cause of the declining population through whaling, ship strikes and fishing gear entanglements. In addition, several biological factors of the right whale have contributed to their endangerment. These factors will be discussed in the following sections.

2.1.1. The History of Whaling

Since the 11th century, humans have been the main predators of North Atlantic right whales. North Atlantic right whales were hunted for their oils and baleen, as both could be sold for large sums of money (Kraus & Rolland, 2010). Whaling companies killed female whales and young whales, not considering the implications of their actions. It was difficult for the species to survive and reproduce as female whales, who could potentially produce more offspring, and calves, who were unable to mature to full grown whales, were being killed off. By the time the prices of whale oils started to decline and the whaling industry began to slow down, there had already been a huge decrease in the right whale population (Kraus & Rolland, 2010). Whaling in the United States finally became illegal in 1935. By that time, however, the North Atlantic right whale had almost become extinct (Scott, 2005). Even though whaling has been illegal for almost 100 years, right whales are still listed as “endangered” and the population of right whales still struggles to increase.

2.1.2. Ship Strikes and Entanglement in Fishing Line

Humans are still responsible for the deaths of most right whales today. Although they are no longer being hunted, North Atlantic right whales are still being killed by ship strikes and entanglement in fishing line (Scott, 2005). A majority of the coastline that abuts the North Atlantic right whale’s habitat has become industrialized, leading to an increase in use by commercial fishing, ship traffic, and naval operations. There has also been an increase in accidental ship strikes and fishing line entanglements in this area (Scott, 2005). A study performed between the years of 2007 and 2011 found that, on average four to five right whales were killed annually due to human activities. Of these deaths, about three right whales died as a result of fishing gear entanglement and about one right whale died due to ship strikes (NOAA, 2014). These deaths are very significant to the right whale population as there are only about 500 left in the world (Pettis & Hamilton, 2014). In comparison, the Southern right whale has a population over 10,000, and appears to be increasing 7.2% per year (Kraus, Brown, Caswell, Clark, Fujiwara, Hamilton, Mayo, 2005).

Ship strikes are usually fatal, often causing head trauma and brain hemorrhaging. If these strikes do not initially kill the whale, injuries sustained in the collision will most likely prove fatal as they make it difficult for the whale to eat or swim. Whales are also often cut by the propeller of the boat and bleed out, as shown in Figure 1 (Kraus & Rolland, 2010).

Figure 1. North Atlantic right whale after a ship strike (GAMMES, 2012)

Entanglement of fishing line is also a major cause of North Atlantic right whale deaths, as seen in Figure 2. Entanglement typically occurs when the right whale is trying to feed. The whales are usually unable to break free from these ropes, and the resulting entanglement causes deep lacerations. These lacerations can lead to infection, or cause the whale to bleed to death. These ropes can also create a drag on the whales, making them even slower and more susceptible to ship strikes (Kraus & Rolland, 2010).

Figure 2. A North Atlantic right whale caught in fishing gear (NOAA, 2010).

2.1.3. Slow Reproduction Rate of North Atlantic Right Whale

In addition to ship strikes and fishing line entanglement, the population of right whales has had difficulty recovering due to their slow reproduction rate. The gestation period of a whale is 12 months, and in that time both the mother and the calf can be killed due to ship strikes and fishing gear entanglement. The average calf production rate per female is 5.25 calves. Therefore, if one female whale is killed, more than 5 potential whales are lost from the population (Scott, 2005).

2.2. Actions Taken To Protect Right Whales

Many actions have been taken to help protect right whales. The NEAq has dedicated a large portion of its time to conserving North Atlantic right whales, including encouraging the enforcement of nautical laws and continuing research efforts in order to better understand the species and their habits. Additionally, the Aquarium is also an integral part of the North Atlantic Right Whale Consortium, an international group of researchers dedicated to right whale research and conservation. The following subsections outline more specifically the work being done to protect North Atlantic right whales.

2.2.1. Shipping Laws

Ship strikes are responsible for about 3 out of every 4 North Atlantic right whale deaths per year (NOAA, 2014). It is critically important to make changes to boating and shipping laws if the whales are to be protected. Some actions have already been taken, including reducing ship speeds in North Atlantic right whale territory and entirely rerouting commercial and military ships to areas where there are less right whales (Scott, 2005). Figure 3 below illustrates one example of the rerouted shipping lanes as designated by the NEAq. The NEAq is responsible for the use of a geographic information system (GIS) to record ship traffic and speeds. Knowing this information and the distribution patterns of right whales, the NEAq can help better refine speed limits and shipping routes necessary to keep North Atlantic right whales safe (NEAq, 2015b).

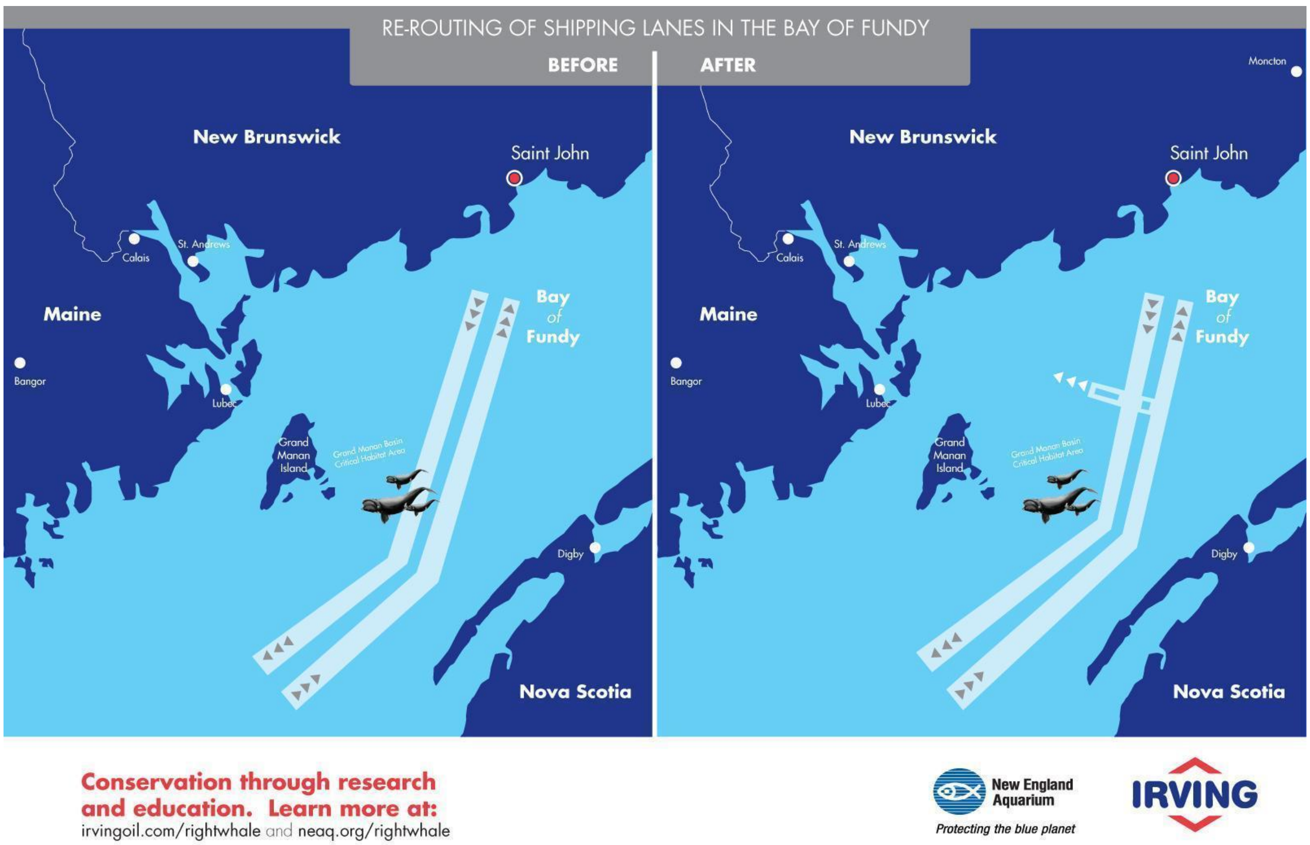

Figure 3. Shipping lanes in the Bay of Fundy rerouted by the NEAq to avoid North Atlantic right whales (Re-Routing of Shipping Lanes in the Bay of Fundy, 2014).

2.2.2. Fishing Regulations

Lethal injuries sustained from fishing line entanglements account for about ¼ of North Atlantic right whale killings annually (NOAA, 2014). Just as laws have been developed to make ship strikes less likely, new regulations are being put in place to reduce fishing line entanglements. These regulations include requiring the use of alternative fishing gear or eliminating the amount of fixed fishing gear (Scott, 2005). The Aquarium is also using GIS technology to record where commercial fishing occurs, and the fishing equipment used in certain areas. This information can be used to tell fisherman where it is safe to fish and set up their fishing equipment (NEAq, 2015a).

2.2.3. Educational Efforts

In addition to the laws and regulations that have been put in place, many museums and aquariums around the world offer exhibits showcasing whales in an effort to raise awareness and encourage the public to make informed decisions. One example is housed at the Natural History Museum in London, England. A two-story exhibit hall within the facility features a model of a blue whale suspended from the ceiling, spanning the entire length of the room. An observation deck around the second floor puts visitors at eye level with the massive species, prompting one visitor to note “It can be hard to believe that you are really looking at a real skeleton of a real animal. That's what is so great about this gallery, it really makes you stop and think” (Tilmouth, 2015). Another exhibit, shown in Figure 4 and located in Portland, Maine, uses light, sound, and movement to create a unique experience for visitors. Developed from skeletons of minke, fin and pilot whales, the exhibit encourages the visitor “to consider human impacts on marine habitats in a contemporary expression of the whales’ experience of humanity”, according to the creator (Schreiber, 2013). Exhibits like these are important to making an impact on the public and helping them develop a deeper understanding of and appreciation for species like the North Atlantic right whale.

Figure 4. Whale bone exhibit at the Institute for Contemporary Art, Maine College of Art (Schreiber, 2013).

2.3. Aquarium Exhibits as a Means of Educating the Public

Any education received outside a typical classroom setting is known as informal education, and is important to the education of the general public. Museum and aquarium exhibits are two vitally important examples of informal education. Informal education in the form of exhibits help visitors to further grow their knowledge on a wide variety of subjects, and develop a deeper understanding and appreciation of subjects not possible in traditional education (Larson & Sincero, 2005). The following subsections outline the process of designing a museum or aquarium exhibit.

2.3.1. Exhibit Design

One major goal of an exhibit is to educate visitors about a specific topic in an informal learning setting. Given this goal, there is much to be considered when designing a new exhibit. Several researchers specializing in exhibitions outlined what they believe to be the three components of exhibit design: the characteristics of the exhibit object or animal, the exhibit architecture, and the visitors (Bitgood & Patterson, 1987).

The first area of exhibit design, characteristics of the object or animal, focuses on the subject of the exhibit itself. In addition, this area also focuses on the accuracy of the information presented in the exhibit, as well as how the information is conveyed to the visitor. For example, an exhibit at the Museum of Science, Boston, focuses on teaching visitors about the major factors affecting digital music quality (bitrate and sample rate). The exhibit allows for visitors to listen to several different audio clips and make changes to the quality settings in real time.

The second area of exhibit design, the exhibit architecture, focuses on the physical design of the exhibit. For example, the lighting and exhibit area. If an exhibit is poorly lit, or constantly overcrowded, visitors are less likely to approach the exhibit (Bitgood & Patterson, 1987).

The third area, the visitors, focuses on the intended audience for the exhibit. Depending on the target audience, the design of the exhibit may change. For example, the Amazing Jellies exhibit, no longer on display at the NEAq, was most popular amongst older adults, age 45 and up (People, Places & Design Research, 2004). The exhibit was designed to attract older, more mature audiences by featuring a serious message, and less hands-on activities compared to other exhibits.

These characteristics go hand-in-hand with another researcher’s measures when determining exhibit effectiveness: attracting power, holding power and communicating power (Donald, 1991). Respectively, these measure an exhibit’s ability to draw in visitors, keep visitor’s attention and convey a message to visitors. Attracting power, holding power, and communicating power are also considered by the NEAq when designing their exhibits.

In addition to attracting power, holding power, and communicating power, the NEAq also works to ensure open communication between visitors and a NEAq staff interpreter where visitors may observe an exhibit on their own, and then refer to a staff interpreter to answer any questions they may still have. This interpreter provides more in-depth information to visitors seeking to expand their aquarium experience. Unlike simply reading information, this interpreter can adjust his or her language and vocabulary to suit different demographics, providing a better understanding of topics for visitors.

2.3.2. Emerging Technologies in Exhibits

In recent years, exhibits have become increasingly more technologically driven. Implementing technology in exhibits can attract visitors, hold their attention, and communicate a message in a way that allows visitors to experience exhibits in ways not previously possible. For example, in 2007 a team of scientists and professors worked to develop an exhibit for the Vancouver Aquarium that utilized technology instead of bringing a live whale into an aquarium. This exhibit allowed guests to interact with a virtual tank filled with virtual animals that have been programmed to grow, learn, and behave much like a tank of live animals would (DiPaola, Akai, & Kraus, 2007).

Even more recently, in August 2015, the British Museum launched its first virtual reality exhibit, allowing visitors to interact with digital recreations of three Bronze Age objects. Visitors can wear virtual reality helmets and examine the recreations up-close. The exhibit is coupled with genuine artifacts, to encourage visitors to continue to learn from the physical objects themselves (Kennedy, 2015).

Similar methods could be used at the NEAq to develop a new exhibit that would attract and hold the public's attention, while also communicating to them the plight of the North Atlantic right whale. Such an exhibit would allow visitors to experience what it would be like to be around an actual right whale, hopefully helping to develop a stronger connection between visitors and the animals.

2.4. Emerging Technology

By choosing an effective method to convey information, such as an emerging technology, museums can create exhibits that excel in the categories of attracting power, holding power, and communicating power. This section examines several emerging technologies that have possible applications within museum or aquarium environments. Touch screens and radio frequency identification (RFID) can add a new level of interactivity to an exhibit. Virtual reality, augmented reality and mixed reality allow for viewers to experience different digital worlds. While virtual reality completely immerses visitors in a digital world, augmented reality and mixed reality blur the lines between the physical world and the digital world. Projection mapping can change the way visitors see the world around them, projecting digital images on three dimensional (3D) objects. All of these technologies have the potential to be used in an exhibit at the NEAq to help people learn more about North Atlantic right whales and the NEAq's efforts to protect them. The following subsections go into detail explaining how these technologies are currently being used and their potential exhibit applications.

2.4.1. Touch Screen Technology

A touch screen is “an electronic visual display that can detect the presence and location of a touch within the display area” (Jain, Bhargava, Rajput, 2013). These screens are commonly seen in use in a wide variety of devices, including but not limited to smartphones, tablets, and GPS navigation systems. Touch Screens are also in use in many exhibits around the world, and can be used to enhance visitor experience and encourage learning in ways never before possible. For example, touch screens can be connected to a computer in order to allow for browsing of additional content regarding the exhibit. An example of touch screens in use can be seen in the Museum of the American Indian in Washington, DC, where part of the museum’s main artifact collection is “linked” to touch screens. These touch screens allow for zooming and 360-degree rotation of digital recreations of these artifacts, providing visitors with the opportunity to inspect the artifacts in ways not permitted within a typical exhibit (Hafner, 2004).

The NEAq also has touch screens set up around the Aquarium. For example the larger screens in the Blue Planet Action Center, as depicted in Figure 5 below, provide data to multiple users at once through multitouch technology. Various “bubbles” containing pictures of creatures float up the screen from the bottom. When touched, these bubbles expand with detailed information about the creature selected. Additionally, there is a system set up around the penguin exhibit at the NEAq utilizing iPad technology. Each penguin in the exhibit is marked with a unique, color-coded identification tag. The person interacting with the exhibit can use the iPad to select the color combination that matches the tag of a penguin in the exhibit. The app on the iPad then pulls up detailed information unique to that specific penguin. The NEAq strives to convey information that could not be simply researched on the internet, and the iPads placed around the penguin exhibit do just that. Touch screens, as well as devices with integrated touch screens, are a major component of exhibits in many museums and aquariums.

Figure 5. Touch Screens at the Blue Planet Action Center at the NEAq (New England Aquarium, 2015c).

2.4.2. Virtual Reality

Unlike touch screen technologies which are generally designed to complement an exhibit, virtual reality (VR) technologies would comprise most, if not all, of a specific exhibit that they are implemented within, due to their immersive nature. The primary use of virtual reality technologies are to immerse users in an artificial, three-dimensional environment. One such example of this technology is a virtual reality theater, as depicted in Figure 6, which was constructed for the "Mayan Civilization" exhibition at the Science Museum in Tokyo, Japan in 2003. This theater allowed those visiting the exhibit to experience digitally reconstructed renderings of Copan ruins. The goal of this exhibit was for the visitors to "step into" the world that was being presented to them (Hirose, 2005).

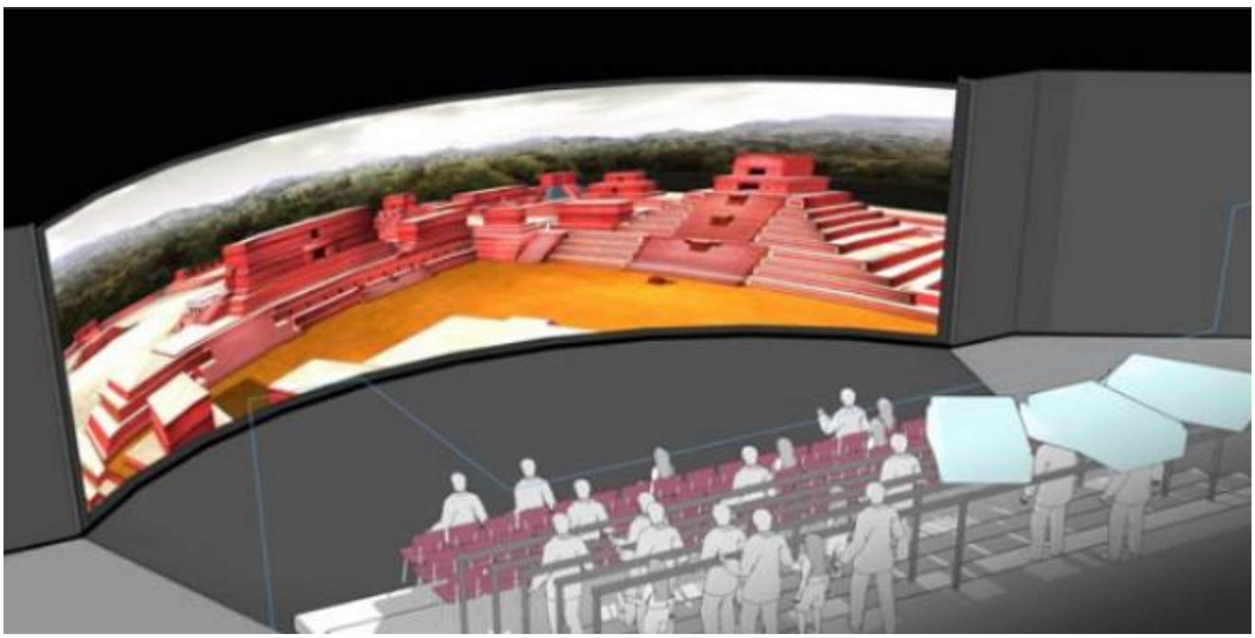

Figure 6. Mockup of the VR Theatre used for the "Mayan Civilization" exhibit (Hirose, 2005).

In more recent years, virtual reality has experienced major developments in the video gaming industry. Various virtual reality headgear are in development, such as the Oculus Rift, in Figure 7, the HTC Vive, and the Sony PlayStation VR. While all of these devices are at different stages of development, it is clear they will all function similarly. All of these devices have two screens, one for each eye, and use various computational techniques to immerse the user in a simulated, virtual world. Just like the VR theatre in Japan, these personal VR technologies also have potential exhibit applications.

Figure 7. A prerelease version of The Oculus Rift virtual reality headset (Oculus Rift Development Kit 1, 2014).

2.4.3. Augmented Reality

Augmented Reality (AR) technologies are designed to “dynamically blend real-world environments and context-based digital information” (Sommerauer and Müller, 2014). One form of augmented reality technology uses the video feed from a camera, analyzes it, and overlays additional information on a display. An example of this technology at work would be the augmented reality portion of the The Ultimate Dinosaurs: Giants From Gondwana exhibit. This exhibit was located at the Royal Ontario Museum in Toronto, Canada, and allowed visitors to use Apple iPhones and iPads to “virtually flesh” the dinosaur skeletons. This technology is illustrated in Figure 8. Augmented reality has the potential to allow people to learn more effectively from an exhibit when compared to an exhibit that is accompanied only by traditional, physical displays (Sommerauer and Müller, 2014).

Figure 8. An example of the Augmented Reality for the Ultimate Dinosaurs at the Royal Ontario Museum (Augmented reality puts flesh on dinosaur bones, 2014).

2.4.4. Mixed Reality

Mixed Reality technology takes input from the real world and imports it into an immersive virtual world (Hirose, 2005). One common example of a large-scale implementation of mixed reality technology is a flight simulator, in which a pilot interacts with a combination of real controls and digital imaging to simulate flying an airplane. This technology is also in use in the museum world. For example, at the Museum of Science in Boston, there is an exhibit, shown in Figure 9, where visitors can design a roller coaster on a computer. Using mixed reality, visitors can then experience what it would be like to ride the roller coaster they just created by entering a self-contained pod equipped with large display screens. This pod also physically tilts in coordination with the roller coaster design being experienced by the participant.

Figure 9. Thrill 360° roller coaster simulator at Museum of Science, Boston (Thrill Ride 360°).

2.4.5. Projection Mapping

Projection mapping technology operates similarly to standard video projection, such as video projectors found in a classroom. However, videos and images in projection mapping are displayed on 3D surfaces, as opposed to a flat projector screen. In addition, some projection mapping software can alter the image displayed, depending on user interaction with the 3D surface.

For example, Poolaid is a billiards table that utilizes projection mapping. The projection mapping software analyzes where the cue ball is located in relation to the cue stick, and helps players align their shot by drawing a line on the billiard table (Sodhi, 2015). The table can be seen in Figure 10.

Projection mapping has also been used in a wide variety of museum and aquarium settings. For example, the Sumida Aquarium in Tokyo has a projection mapping show titled “Penguin Candy”. During the show, projectors are used to project images onto the rocks of the penguin exhibit and give the appearance of the water changing colors. Visitors can then watch the penguins swim around in the projection mapped pool. The exhibit can be seen in Figure 11.

The Sumida Aquarium has also used projection mapping to bring humpback whales into the Aquarium, through a projection mapping show. Rather than using live humpback whales, the Aquarium projects the whales into a tank, alongside other fish, allowing visitors to experience the size and scale of the whales, without actually placing the whales inside the Aquarium ("Water Tank Projection Mapping", 2014).

Figure 10. The "Poolaid" table, using augmented reality (Sodhi, 2015).

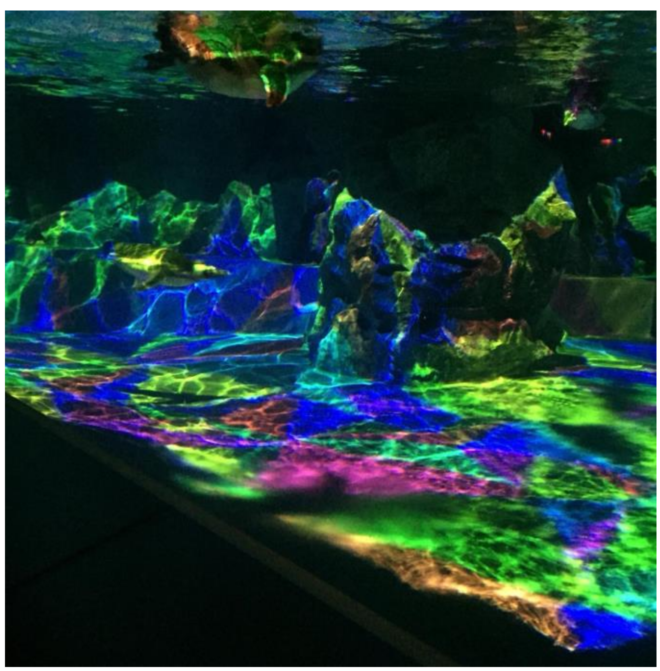

Figure 11. Projection Mapping of the "Penguin Candy" Exhibit as the Sumida Aquarium (Nogata, 2015).

2.4.6. Radio Frequency Identification

Radio Frequency Identification (RFID) has wide uses in other fields but is just starting to emerge within the museum environment. This technology uses small chips embedded in or attached to devices to transmit data to a RFID reader. This technology is commonly used for security doors, where someone only has to tap his or her RFID-enabled ID Card to an RFID card reader to gain access. Three engineers, one from the Electrical and Computer Engineering Department at the Meghnad Saha Institute of Technology and two from the Electrical and Telecommunications Engineering Department at the Jadavpur University, published a proposal regarding RFID technologies in museum exhibits. Their proposal involved utilizing an active RFID tag, two language buttons (Hindi and English), a processor, and an audio system with a headphone jack. Upon entry into the museum, a visitor is supplied with this device and simply has to walk up to an exhibit and press either the Hindi or English button on the unit to hear more about the exhibit in that language (Sen, Roy & Sarkar, 2014).

2.4.7. Handheld Computers

Another similar technology in use at museums is handheld computers. For example, the Getty Museum in Los Angeles let visitors borrow handheld computers before the opening of a major Jacques-Louis David exhibit in February of 2004 (Hafner, 2004). These computers contained information about the entire collection of the museum, and this information could be tailored to individual visitors based upon the individual's interests, therefore allowing for a more personal exhibit experience. According to executive director for digital policy at Getty, the use of hand-held computers was in reaction to the failures of stationary installed kiosks. The museum's own assessments determined that visitors often forget the name of a painting that they were interested in learning about before reaching a kiosk (Hafner 2004).

2.4.8. The Impact of Technology on Exhibits

According to the vice president and research analysts of Slover Linett Audience Research, technology has the ability to vastly improve the experience of visitors in a museum environment (Lee & Okeke, 2014). It also, however, has the potential to damage these experiences. Technology can easily become distracting, a major concern when implementing technology in an exhibit. Exhibit designers do not want the technology in use to become the main focus of the visitor. There are some data on this subject, but Slover Linett Audience Research's report claims that "no recent study that [they are] aware of has attempted to systematically examine visitor experience preferences with respect to technology in museums and to segment visitors based on those preferences" (Lee & Okeke, 2014). Their study attempted to rectify this issue, however they also mention that their results may not apply outside of the Field Museum where they conducted research. When conducting our analysis, we wanted to ensure that technologies would attract and entertain visitors without distracting from the message being communicated through the exhibit.

2.5. Background Summary

By raising public awareness, action can be taken to help protect the endangered North Atlantic right whale. Through an aquarium exhibit, more people will be able to learn about the dangers the right whales face and the actions they can take to help protect the species.

Museum exhibits are a form of informal education used to further grow the public's knowledge about topics that interest them. When designing an exhibit, it is important to consider the attracting power, holding power, and communicating power of the exhibit. Specific to the NEAq, a connection between visitors, the exhibit, and a staff interpreter can be extremely beneficial to the visitor's experience.

There are various technologies that can be used in a museum or aquarium environment. Technologies such as touch screens are already widely in use in museums and aquariums around the world. Although other emerging technologies, such as RFID, augmented reality, virtual reality, and mixed reality, are not as widely in use, there are situations where these technologies have been used or proposed for use in a museum or aquarium environment. All of these technologies have potential to allow people to learn better in these informal educational environments. However, more research must be done in order to determine what specific aspects of technology improve upon a visitor's interaction with an exhibit. In particular, more research must be done on how these technologies affect the attracting power, holding power, and communicating power of an exhibit, without distracting visitors from the overall message of the exhibit.

3. Methodology

The goal of our project was to identify and analyze emerging technologies that have the potential to be used at the New England Aquarium to educate the public on the dangers facing the North Atlantic right whale, and captivate visitors about the wonders of the animal. In order to accomplish our project goal, we:

1. Identified characteristics of exhibits that attract, hold the attention of, and communicate the intended message to visitors
2. Developed exhibit design criteria based upon identified characteristics
3. Analyzed emerging technologies that could be implemented in a right whale exhibit using the exhibit design criteria.

By assessing technologies, we created a matrix to compare the strengths and weaknesses of potential options with respect to exhibit design criteria related to attracting power, holding power and communicating power.

In the following sections, we explain our methods for determining characteristics that accomplish our defined exhibit goals and then developing criteria based upon these characteristics. Finally, we explain our system for using the criteria to analyze emerging technologies in an informal education environment.

3.1. Identified Characteristics of Effective Exhibits

As established in our literature review, museum exhibits work best when designed to attract, hold the attention of, and communicate a message to the visitors. We sought to identify how these characteristics would be measured and applied to a right whale exhibit.

In order to establish which exhibit features attract and hold NEAq visitors' attention, as well as how to communicate to our audience, we first examined literature. It was then necessary to conduct interviews in order to identify additional features and confirm those we already found to be important. This approach allowed us to compile a complete list of characteristics which would attract and hold the attention of NEAq visitors, as well as communicate the intended message of the exhibit.

3.1.1. New England Aquarium Visitor and Exhibit Data

Information about the NEAq visitors was obtained through past IQPs and MQPs, as well as data the Aquarium had previously collected. We used the information about the NEAq visitors to determine what the visitors liked and disliked about certain exhibits, and what the visitors would like to see. The past IQPs and MQPs were easily accessible to us online. From these reports, we were able to extract information such as the average visitor age and the types of groups that visited the Aquarium. A NEAq employee presented us with several graphs, which highlighted the popularity of exhibits within the Aquarium. We were able to see the popularity trends between exhibits containing animals and exhibits without.

3.1.2. Museum and Aquarium Staff Interviews

Throughout the interview process, we obtained consent to interview all participants. We also maintained interviewees' privacy by not identifying them by name. The first interviewee (referred to as NEAq Employee A) is responsible for visitor experience and exhibit design at the NEAq. This interview served as a valuable resource as we began gaining insight into the planning and design of exhibits at the NEAq.

We focused our questions on popular exhibits and the characteristics they possess that allow them to attract and hold the attention of visitors. In addition, we discussed what the goal or goals of a NEAq exhibit are, and which specific excel at communicating these goals to visitors. The specific questions asked during this interview can be found in Appendix A.

The second interviewee (referred to as NEAq Employee B) is responsible for designing and prototyping exhibits to determine the most effective method for presenting content. We asked many of the same questions as those we asked NEAq Employee A. Both employees work together on the exhibits and thus may provide us with different perspectives on the same topics. The specific questions we asked NEAq Employee B are listed in Appendix B.

The third NEAq Employee (referred to as NEAq Employee C) is responsible for setting up and operating technology based exhibits. In addition, NEAq Employee C also performs general upkeep and maintenance of exhibits within the NEAq. Questions for NEAq Employee C were focused on integrating technology into exhibits in order to attract and hold visitors attention, as well as effectively communicate the intended message. We also discussed the problems that face technology based exhibits, especially within a setting such as the NEAq where the health and wellbeing of the live animals on display must also come into consideration. Our specific interview questions for NEAq Employee C can be found in Appendix C.

Boston Harbor Cruises (BHC) works alongside the NEAq to supplement the NEAq's lessons on marine life with trips out into the waters around Boston. North Atlantic right whales, as well as several other species of whale, can be found in this region. BHC and their whale watch tours serve an important role in educating visitors and getting them excited about whales. As a result, we interviewed one of their employees (referred to as BHC Employee A) in order to gain insight on why visitors choose to go on whale watch tours and what BHC employees hope visitors gain from their whale watch experience. While interviewing BHC Employee A, we focused on answering two key questions: "What about whale watches and whales in general excites visitors? and "What information is important to convey to visitors about the North Atlantic right whale?", and by answering these questions, we were able to determine what type of information would excite NEAq visitors if included in an exhibit. Knowing what information excites visitors allowed us to consider how to convey this information effectively through an exhibit. Our specific questions can be found in Appendix D.

Through interviews with staff at a science museum, we learned how they effectively communicate ideas through technology, as well as how visitors interact with the technology available. In addition, we also learned more about the exhibit design process. This interview provided us with information that helped us to further develop criteria that must be considered when developing effective exhibits. Our specific questions for this interview can be found in Appendix E.

While conducting our interviews, we ran into one major limitation. We reached out to two other museums and aquariums outside the New England area about conducting interviews, but never heard back from either facility.

3.2. Developed Exhibit Design Criteria

Based on our interviews, we developed a list of characteristics an "effective exhibit" should possess. We had asked each interviewee to define what they believed to be an "effective exhibit", then asked them to provide an example of one exhibit they would define as "effective". Asking probing questions about the interviewee's example exhibit allowed us to determine specific characteristics that the exhibit had which made it "effective". When analyzing interviews, we gathered all of the characteristics of effective exhibits and merged them with the characteristics gathered from our literature review.

Using the characteristics that we identified as crucial to an exhibit that attracts visitors, holds their attention, and effectively communicates a message, we began to develop our design criteria. This process required us to organize the characteristics we found in our previous objectives based on how they fit the definitions of the three powers, combining identical characteristics which appeared in multiple interviews and resources to avoid being redundant. If a characteristic fit into multiple categories, we chose whichever we felt it related to more closely.

3.3. Analyzed Emerging Technologies

After developing our design criteria, we analyzed the emerging technologies. We first determined which emerging technologies would be analyzed. Because it would be difficult to analyze some technologies without applying them, such as the concept of virtual reality, we defined several exhibit concepts, which utilized the identified technologies. We then analyzed and compared these exhibit concepts, allowing us to easily compare the technology used in each of them. In the following sections, we will expand on our methods of identifying technologies, and comparing them.

3.3.1. Identification of Emerging Technologies

We identified which emerging technologies from our literature review we would analyze based on our interviews. Technologies that were never discussed in interviews were not analyzed because they did not appear to be on the forefront of new exhibit design. As a result, we focused our analysis on five technologies: virtual reality, augmented reality, mixed reality, touch screens, and projection mapping. We did not further analyze RFID or personal computers.

Additionally, there may be other technologies suitable for museum or aquarium environments that are not covered in our report. It is important to note that interviews with aquarium and museum staff did not identify any technologies that we had not previously researched in our literature review.

3.3.2. Developing exhibit design examples

Using the previously developed characteristics, as well as the identified technologies, we developed several exhibit designs. The first crucial step, however, in developing these designs was to consider the information that should be conveyed through the exhibit. Currently, the only exhibit on display at the NEAq specifically dedicated to the North Atlantic right whale is a whale skeleton, despite all the NEAq's efforts to research and protect the species. A new exhibit at the NEAq should aim to educate visitors on North Atlantic right whales, inform visitors of the NEAq's work for the whales, and encourage visitors to do what they can to help protect the whales. We then identified exhibit examples in other museums and aquariums that utilize similar or identical technologies, and applied these designs to an exhibit about the North Atlantic right whale. These exhibit ideas are meant to be used to help inspire others and provide some practical applications for the technologies analyzed in this report.

3.3.3. Analyzed Emerging Technologies

We developed a ranking system to systematically compare our exhibit design ideas in an easy to read format. First, we went through each design criteria and used the explanation of each provided in our interviews to develop a quantifiable definition for each characteristic. We then defined a "middle-ground" for each characteristic. In other words, how might an exhibit partially have the characteristic? For example, we defined the "physical design" characteristic as "having adequate space and lighting" and therefore, an exhibit that partially had this characteristic would have "adequate space OR lighting".

Once we developed a full list of characteristic definitions, we then determined to what degree each exhibit design fit into a definition. If the design fit the definition exactly, we gave it a "+" ranking in regards to that characteristic. If the design partially fit the definition, gave it a "0" ranking. Finally, if the design didn't fit the definition, we gave it a " - " ranking.

Additionally, we compared the price of the technology hardware, space requirements, upkeep requirements, animal accommodation, and durability for each technology using a similar process. Using web searches, we first identified an average cost range of the technology hardware, and any technology within this range received a "0" ranking. Any technology with a cost below the average range received a "+" ranking and any technology with a cost above the range received a " - " ranking. For other identified limitations, we developed definitions for each. Similarly, we then defined a "middle-ground". For example, a positive in animal accommodation was defined as "no risk to animals" while a negative was defined as "not suitable for use around animals” and a “0” was defined as “modifications may need to be made to allow for use around animals”.

Using the defined characteristics and limitations, we rated each exhibit. We then placed these rankings into a matrix, allowing us to more easily compare results.

4. Discussion

North Atlantic right whales are among the largest animals on earth. Human actions have led to a decline in their numbers, and there are now less than 500 North Atlantic right whales left in the ocean (Pettis & Hamilton, 2014). Fortunately, educating the public on the whales can help them develop a deeper understanding and appreciation of the species, allowing them to make their own, informed decisions on aiding in conservation of the whales (Larson & Sincero, 2005). Museum and aquariums offer a forum for public education. An effective exhibit at the NEAq can play an important role in informing the public about North Atlantic right whales and the NEAq's conservation efforts. This chapter outlines characteristics we identified as those belonging to effective exhibits, as well as nine ideas for potential exhibits, and an analysis of each potential exhibit using the identified traits.

4.1. Characteristics of Effective Exhibits for Right Whales

Using the methods explained in Section 3.1, we conducted interviews with people holding positions involved with museum and aquarium exhibit design and maintenance, as well as people involved more directly with North Atlantic right whales. The following subsections describe the thirteen characteristics we developed. Section 4.1.1 relates to attracting power, sections 4.1.2 and 4.1.3 relate to holding power and sections 4.1.4 and 4.1.5 relate to communicating power. The remaining sections, 4.1.6 to 4.1.8, relate to limitations of the technology analyzed, Additionally, these characteristics can be found in Appendix F where it outlines which power category (attracting power, holding power, communicating power or limitation) each characteristic fits within, noting which characteristics also fit into more than one category.

4.1.1. Exhibits Should Possess "Wow Factor"

One important characteristic of an exhibit that attracts and holds visitor attention is "wow factor". An employee at the NEAq described "wow factor" as an exhibit that is unique, whether it is exceptionally "unusual, large, strange, or cute". The employee claimed that the initial spark of interest in something unusual, large, strange, or cute often attracts visitors to an exhibit.

Further discussion of the “wow factor” brought up one particular exhibit within the NEAq known as the Seadragons Exhibit, shown below in Figure 12. This exhibit, while relatively small in scope, features several very interesting sea creatures. Despite being a simple exhibit, it has proved popular among visitors and has earned an excellent rating (a score of 9 or 10 on a scale of 1-10) among 82% of polled visitors since summer of 2013. These data are based on an ongoing visitor survey conducted by the NEAq. Results of this survey are presented in the graph in Appendix G.

Figure 12. The Seadragons Exhibit featured at the NEAq (Finished Project, 2012).

Whales have several characteristics which may be considered a “wow factor” such as their sounds and breaching. However, the most immediately apparent characteristic is its large size. The whale’s large size is part of the “wow factor” that excites visitors attending whale watches, and attract them to such events. An employee of a whale watch tour company informed us that “most people come on a whale watch... hoping that [whales] come right up to the boat”.

4.1.2. Exhibits Should be Interactive

Exhibits that are interactive tend to attract and hold the visitors attention. For example, at the NEAq there is a Turtle Rescue exhibit, shown in Figure 13 that displays model turtle replicas and allows visitors to use a wand to help treat these turtles. When the wand touches a certain area of the turtle, a screen located with the exhibit displays a video of veterinarians treating sick turtles. According to NEAq visitor surveys (results shown in Appendix G), this exhibit scored just as well among visitors as live exhibits in the Aquarium. NEAq Employee A attributed this popularity primarily to the interactive nature of the exhibit.

Figure 13. The Turtle Rescue exhibit currently featured at the NEAq (Turtle Rescue Exhibit, 2015).

Another interactive exhibit that visitors scored just as well as live exhibits was the Blue Planet Action Center, pictured in Figure 5 (Chapter 2). This exhibit consists of three large touch screens displaying pictures of different sea creatures floating around in bubbles. Touching these bubbles brings up more information about the animals.

4.1.3. Exhibits Should be Immersive

Another important quality as determined by our interviews is a visitor's immersion in an exhibit. NEAq Employee A specifically stated immersion as a factor of effective exhibits. Immersion is defined as "deep mental involvement" in a subject. Immersion contributes to an exhibit's communicating power, or how effectively an exhibit can communicate the desired message to visitors. Providing a fully immersive setting in which to learn allows visitors to block out distractions and focus more completely on the exhibit in front of them. Lighting and background music can be used to develop a mood for an exhibit - whether that be the joy of exploring an exciting tropical rainforest or the fear of the dark deep sea.

While no longer on display, an exhibit titled Amazing Jellies, shown below in Figure 14, was provided as an excellent example of full visitor immersion. This exhibit featured low lighting and foreboding music to compliment the overall theme of the exhibit: that humans are impacting- often negatively- the ocean, and yet these seemingly negative effects provide an environment in which jellyfish can thrive. Visitors walking through this exhibit not only got to see jellyfish swimming and read about the negative impact of humans on the environment and how that affects the jellyfish, but also became fully immersed in this dark undersea world. According to an in-depth analysis conducted by the NEAq, 60% of visitors stayed at this exhibit for 20 minutes or longer, a major increase from the average time of 2 minutes (People, Places & Design Research, 2014). NEAq Employee A attributed the strong holding power of the jelly exhibit to how well it immersed visitors.

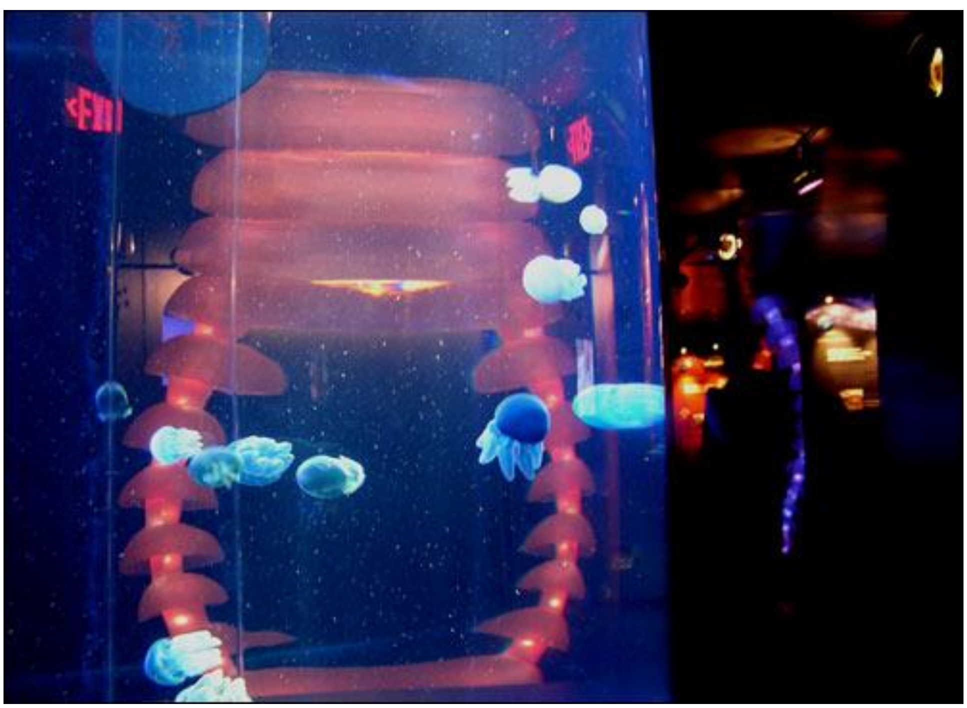

Figure 14. Amazing Jellies Exhibit formerly featured at the NEAq (Dalager).

Another example of an immersive exhibit is the Giant Ocean Tank in the center of the NEAq. The tank provides 360 degree viewing of the sea life within, broken up into smaller viewing windows. These windows act almost as blinders, shutting visitors off from the rest of the aquarium and allowing them to fully immerse themselves in the world of the tank and to really experience the animals swimming within. Since the summer of 2013, 92% of polled visitors rated the Giant Ocean Tank as "excellent", as shown in the graph in Appendix G. Immersion is important in creating deeper personal connections between visitors and the animals on display at the NEAq.

Creating a personal connection between visitors and staff can also help immerse visitors in an exhibit. The NEAq employs staff members to further explain exhibits to visitors and answer any questions that may be asked. These employees provide visitors with the opportunity to ask questions about the exhibits that interest visitors, and allows staff to tailor their responses based on the specific visitor asking questions.

4.1.4. Exhibits Should be Multigenerational

A multigenerational exhibit, one which encourages interactions between age groups, can help exhibits to communicate more effectively to visitors, and attract broader audiences to the exhibit. According to a previous IQP, "Framework to Develop a North Atlantic Right Whale Video Game", visitor groups are generally comprised of "two adults and one child" (Anina et al. 2014). These multigenerational groups make up a majority of NEAq visitors, and thus, it is important to develop exhibits that can be experienced by these groups together.

NEAq Employee A also stated that it is important for NEAq exhibits to encourage human interactions and be enjoyed by all ages. One exhibit that has proved to possess this quality is the Turtle Rescue exhibit. Typically, parents or guardians are required to help children figure out how to use the exhibit, or help them if they cannot reach a portion of the exhibit. This ensures that an entire family uses and learns something from the exhibit.

4.1.5. Exhibits Should be Focused on Education

The NEAq emphasizes the use of education in all of their exhibits. A focus on education supports the communicating power of exhibits. According to NEAq Employee C, education is really the main focus of all of the exhibits. NEAq Employee B explained that while in the process of designing a new exhibit, they usually start out with the content they would like to display in that exhibit and then they determine how they will convey this information to visitors. The Turtle Rescue exhibit attracts and holds the visitor's attention by being interactive and multi-generational, but once it has the attention, it communicates the message of the conservation efforts the NEAq puts forth with the turtles.

In regards to our project, our sponsor would like to showcase the research, the conservation efforts, and the projects the NEAq is working on regarding the North Atlantic right whale. We contacted a whale watch company to find out other information this exhibit should communicate to the NEAq visitors based on the questions and reactions they have gotten from the whale watch. As reported by BHC Employee A, typically visitors want to know “the basics” of the whales, including the type of whale they are seeing, the size of the whale, how old it is, and so on. Once visitors have an interest in the whale, BHC can then move on to more serious issues, telling visitors about the actions they can take to protect the whales- the same goal of as NEAq.

In addition to focusing on education, exhibits should also work with each other to convey a common message and better communicate the NEAq’s overall goals of conservation and exciting visitors about animals. This characteristic supports the communicating power of an exhibit. As a whole, the NEAq has overarching goals and a story that it aims to communicate to visitors. Conservation is very important to the NEAq. Through their exhibits, they aim to showcase their efforts to conserve the ocean as well as inspire visitors to do what they can to protect aquatic life. NEAq Employee A informed us that there are not currently any exhibits within the NEAq that function independently of the rest of the exhibits. For example, an interactive exhibit in the basement of the facility that showcases the NEAq’s efforts to rescue sea turtles compliments the live sea turtles that can be found swimming in the Giant Ocean Tank

4.1.6. Exhibits Should be Durable

When designing an exhibit, it is important to account for wear-and-tear caused by regular, and sometimes excessive, use. NEAq Employee A, as well as the NEAq Employee C, both agreed that certain designs and features are more prone to failure than others. An exhibit with moving parts and hard stops is more likely to experience failure than an exhibit lacking these features. Examples of parts likely to experience failure include exhibits utilizing levers with limited ranges of motions and stiff chords. The NEAq experienced a technical failure within the Turtle Rescue exhibit. An “inspection wand” is used by visitors to interact with the model turtles and “treat” them for medical injuries. This wand is connected to the Turtle Rescue exhibit via a strong chord. However, the NEAq has already had one of these connecting chords break since the exhibit opened in the summer of 2015. NEAq Employee C told us that he was shocked when he heard that the chords broke because they were made from incredibly durable payphone chords, proving that components that may seem incredibly durable can often wear out under the rigorous conditions found in exhibit halls.

One example of how failure can be avoided is by removing problems such as hard stops. Spin Browser technology, pictured in Figure 15, offers a solution to this problem. It consists of a circle mounted to a shaft that spins infinitely, and allows for scrolling through content. Spin Browser technology has been implemented within the NEAq, where it is used to scroll through video content at whatever pace the user sees fit. Visitors simply spin the wheel one way to progress forward, and reverse it to rewind. The advantage to this technology is that there is no hard, physical stop to put stress on the mechanical components.

Figure 15. A Spin Browser (Dome Mount Spin Browser, Temporal Innovations).

Another problem exhibits experience is prolonged wear-and-tear. For example, the Turtle Rescue exhibit is run off of several BrightSign Boxes. This technology, originally designed for digital signage, utilizes a typical SD Card for storage of all required data. The inherent problem with the long-term durability of SD cards comes from the fact that they have a limit on how many times they can be read from or written to. Generally, the limited lifespan of an SD card is not a problem as it is relatively high. Despite this fact, it has become an issue in the Turtle Rescue exhibit. The NEAq has had several cards fail, and are currently working to resolve this issue.

4.1.7. Exhibits Should Work with the NEAq Building

According to NEAq Employee C, the NEAq building itself only has a limited amount of space available. The space limitation requires that exhibit size and layout work with what is available, as additions to accommodate new exhibits are not feasible.

The concrete walls of the NEAq provide other limitations to the technology that can be used within. Concrete is not conducive to wireless radio signals. As a result, most technologies that utilize wireless radios, including technologies that employ Wi-Fi, do not function as well as they could within a building of a different construction. According to NEAq Employee C, this issue has proved problematic in past exhibit development and is important to consider moving when developing new exhibits

NEAq Employee C also stated that the concrete surfaces in the Aquarium do not allow for easy rewiring. Wherever possible, exhibit designers must work with the current electrical wiring, as rewiring would be very labor intensive and tack on heavy additional costs. When re-wiring is not avoidable, exhibit designers work to optimize the efficiency of the re-wiring in order to minimize costs.

4.1.8. Exhibits Should Accommodate Animals

One factor to consider when developing an exhibit is the interaction between the living animals and their surroundings. Exhibits are often designed to complement live animals, and should do so seamlessly, improving visitors' overall experience. When developing our exhibit ideas, it was important to ensure that the use of technology added to visitor experience, and not at the cost of the animals.

Any potential negative health impacts exhibits could have on live animals should also be considered. For example, the penguins at the NEAq are very sensitive to light, and excessive light at the wrong time of day can disrupt their bodily clock. Therefore, light spill into the penguin habitat must be nonexistent overnight so as not to disturb the penguins. According to NEAq Employee B, the NEAq is currently working on a project that will allow for the direct illumination of banquet tables set up around the aquarium perimeter during special events, while avoiding light spillage into the penguin exhibit. Lighting issues must also be considered when evaluating our technologies, specifically projection mapping which requires an extremely bright projector to function. While projection mapping can be used around penguins, such as the "Penguin Candy" exhibit at the Sumida Aquarium in Japan, precautions must be taken. As long as the animal's well-being is considered as a priority when developing exhibits, almost any type of technology could be utilized within the NEAq.

4.2. Example Exhibits

With a focus on the goal of educating visitors on North Atlantic right whales, informing visitors about NEAq's efforts to protect right whales, and encouraging visitors to take their own actions to protect the whales, we then developed nine exhibit ideas. Our ideas were:

- Swim with the Whales virtual reality exhibit
- Interactive Whale Smartphone augmented reality exhibit
- Digital Whale augmented reality exhibit
- Boat Simulator mixed reality exhibit
- Life-Sized Whale touch screen exhibit
- Interactive Video touch screen exhibit
- Swimming North Atlantic Right Whale projection mapping exhibit
- North Atlantic Right Whale projection mapping exhibit
- "Live" Show projection mapping exhibit

Each of these exhibits utilize one of the emerging technologies we identified and exemplifies one or more of the exhibit design characteristics. These characteristics were organized into a matrix, as seen in Figure 16. If the design fit the definition of the characteristic exactly, we gave it a "+" rank in regards to that characteristic. If the design partially fit the definition, gave it a "0" rank. Finally, if the design didn't fit the definition, we gave it a " - " rank. The exact definitions of each characteristic can be found in Figure 17. In the following sections, we discuss the key features of each exhibit, as well as limitations and drawbacks to each exhibit design idea. The following subsections delve deeper into our exhibit ideas, explaining what technology they will utilize and how they aim to educate the public and encourage the public to take actions to protect North Atlantic right whales.

4.2.1. Virtual Reality - Swim with the Whales

A "Swim with the Whales" exhibit would allow visitors to "swim" with digital North Atlantic right whales, using virtual reality goggles, similar to the ones in Figure 7 (in chapter 2.5.2). We designed this exhibit based off of a similar exhibit featured at the British Museum. In that exhibit, visitors could examine re-created artifacts through virtual reality goggles. Both exhibits allow for "up-close" interactions to subjects re-created in virtual reality (Kennedy, 2015).

The exhibit received a "+" rank in the following characteristics: *"wow factor", interactive, immersive, price, space, and animal accommodation*. Using virtual reality to place visitors up close to the whales showcases the "wow factor" of this exhibit, as visitors would be able to experience the size of these massive creatures first-hand. A highly interactive and immersive exhibit would allow visitors to enter a digital environment where they could control how they move around and explore the space, completely captivating visitors' attention. The hardware for this exhibit is estimated to cost less than $10,000, based on the price of one virtual reality gaming headset. Given that the exhibit only requires a visitor to wear virtual reality goggles, this exhibit would not take up much space within the NEAq and thus could utilize space already available. Additionally, the technology used in the exhibit does not cause any risks to the other animals.

Physical design, interpreter, mulitgenerational, focus on education, easily navigated, upkeep, and durability were given a “ - ” rank for this exhibit. The physical design of this exhibit would only include a few pairs of goggles and would lack adequate space and lighting. The design of this exhibit also does not allow for a NEAq interpreter to be present. Interaction with other visitors while using this exhibit would not be possible, therefore this exhibit could not be considered multigenerational. The exhibit would not focus on education, as it only allows the visitors to “swim” with the whales without providing further information about the whales or conservation efforts. Easy navigation of this exhibit would be difficult because it would require the visitor to have prior knowledge of virtual reality goggles. The goggles required for this exhibit are not durable, and could break easily due to rough handling and frequent use. Overall, this exhibit would have strong attracting and holding power, but would lack communicating power. A full ranking of all characteristics for this exhibit can be found in Table 1.

Table 1. Characteristics of “Virtual Reality” exhibit.

Positive Characteristics(+)	“Wow factor”, Interactive, Immersive, Price, Space, Accommodates Animals
Neutral Characteristics(0)	[None]
Negative Characteristics(-)	Physical Design, Interpreter, Mulitgenerational, Focus on Education, Easily Navigated, Upkeep, and Durability

4.2.2. Augmented Reality - Interactive Whale Smartphone Application

A smartphone application would allow visitors to use their smartphones to examine the North Atlantic right whale skeleton currently on display at the NEAq. Visitors could use the application to overlay a skin on the North Atlantic right whale skeleton and receive more information about North Atlantic right whales. The application could also be used throughout the Aquarium, allowing visitors to easily access more information about other exhibits.

We based our phone application design on a similar app used at the Royal Ontario Museum in Toronto. In that exhibit, skin is displayed over dinosaur skeletons so visitors can examine how dinosaurs may have looked. Our exhibit uses an identical concept.

The characteristics of this exhibit that received a “+” rank were *“wow factor”*, *interactive*, *multigenerational*, *focus on education*, *price*, *space*, *upkeep*, *accommodates animals*, and *durability*. The “wow factor” would attract the visitors by allowing them to get up close and see the large size of the right whale skeleton. Interaction between the app and the visitor would be required for this exhibit, which could hold visitors' attention and keep them focused on the right whale. Using the app could encourage interactions between different age groups, since most children do not have smartphones and would have to look on with a parent. Therefore, the exhibit could be multigenerational. This exhibit would also allow for an educational focus. The Aquarium could easily communicate information about the North Atlantic right whale to visitors by allowing them to read the information directly from their smartphone. The app could contain information about the anatomy of the whale, its feeding and migration habits, and stories of whales the NEAq has tracked. In addition, the app would also inform visitors about the dangers these whales face, and the efforts the NEAq has contributed to protect them. There is very little cost to run this application, and there would be no need to make additional space in the Aquarium for this exhibit. The upkeep of this application is minimal compared to the other exhibits, and will most likely only have to be updated monthly. The technology used in this exhibit would cause no harm to the animals in the surrounding exhibits, and would be highly durable. Visitors would use their own smartphones instead of using museum property.

The characteristics that received a "0" rank were *immersive* and *easily navigated*. This exhibit would not be considered totally immersive because visitors are not closed off from other exhibits and would still be aware of what is going on in the Aquarium around them. Prior knowledge of this technology would be required for use, therefore the exhibit would not be considered easily navigated. Visitors without a smartphone, or who are not tech savvy, would be unable to experience the exhibit.

Physical design and *interpreter* earned a " - " rank for this exhibit. This exhibit would not involve a welcoming physical design, since it is an application found on visitors' smartphones. Because this app would work like an exhibit interpreter, there would be no need for an interpreter accompanying this exhibit. While this exhibit could very informative, it lacks attracting and holding power. A full ranking of all characteristics for this exhibit can be found in Table 2.

Table 2. Characteristics of "Interactive Whale Smartphone Application".

Positive Characteristics(+)	"Wow factor", Interactive, Multigenerational, Focus on Education, Cost, Space, Upkeep, Accommodates Animals, Durability
Neutral Characteristics(0)	Immersive, Easily Navigated
Negative Characteristics(-)	Physical Design, Interpreter

4.2.3. Augmented Reality - Digital Whales

Using a standard projector, the Digital Whales exhibit would involve projecting North Atlantic right whales into pre-existing NEAq tanks. The whales would interact with visitors and provide them with more information on North Atlantic right whales. Although a full-sized North Atlantic right whale could not fit in any of the NEAq's tanks, camera tricks could be used to make the whale appear full sized and yet not completely occupying the tank. One example would be to project the back of the tank out beyond the actual end point, so visitors looking into the tank see it as larger than in reality. Additionally, the whale could appear to be swimming further away from visitors, or simply swimming past visitors so that at any one time only part of the whale can be seen. We developed this exhibit idea by examining a similar exhibit at the Sumida Aquarium. In that exhibit, a video of a whale is projected onto a tank, with live fish swimming inside it (Water Tank Projection Mapping, 2014). Our exhibit expands on the concept, by providing more interaction between the projected whale and visitors.

The characteristics this exhibit scored a "+" rank on were *"wow factor", physical design, focus on education, easily navigated, space, upkeep* and *durability*. The projections of this large animal could attract the visitors and make them feel like they have entered the world of the right whale. The physical design would also include adequate space and lighting, which could attract visitors. These projections of the North Atlantic right whale would also be able to talk to and interact with visitors, and sharing facts about the North Atlantic right whales. This would include the dangers North Atlantic right whales face and actions the visitors can take to help protect the whales. This interaction would create a large focus on education, and could effectively communicate the NEAq message to visitors. Visitors would be able to easily navigate through this exhibit, since no prior knowledge is required to successfully use this technology. The exhibit would also be able to fit in space already available at the Aquarium. Any tank could be used, but not all of the whale may be seen when it is projected up close to the glass. The whole whale could be seen further back in the tank. The maintenance of this exhibit would be relatively easy, since most of the time the primary repair would require changing the lightbulbs in the projector. Additionally, this exhibit would be very durable, since there is no visitor interaction or risk of damage.

The characteristics that received a “0” rank were *interactive*, *immersive*, *multigenerational*, *interpreter*, *accommodates animals*, and *price*. The amount of interaction and need for an interpreter would depend on the exhibit design. This exhibit would not be very multigenerational because there would be no need for families to work together and interact with the exhibit. When designing this exhibit, another factor to consider would be safety of the live animals involved. The fish cannot be negatively affected by the projector used to create the digital whale. This exhibit would fall somewhere within the moderate price range, between $10,000 and $100,000, as determined by researching the price of a high-powered commercial projector. Overall, this exhibit could have strong attracting power, but lack holding and communicating power. A full ranking of all characteristics for this exhibit can be found in Table 3.

Table 3. Characteristics of “Digital Whale” exhibit.

Positive Characteristics(+)	“Wow Factor”, Physical Design, Focus on Education, Easily Navigated, Space
Neutral Characteristics(0)	Interactive, Immersive, Multigenerational, Interpreter, Price, Upkeep, Accommodates Animals, Durability
Negative Characteristics(-)	[None]

4.2.4. Mixed Reality - Boat Simulator

A boat simulator exhibit would allow visitors to captain a fishing vessel and make decisions which would impact North Atlantic right whales. This exhibit would be similar to a flight simulator, in which the NEAq visitors enter a pod, similar to the one shown in Figure 9 (chapter 2), containing screens that display the view from the boat. The room would be able to move and simulate the movements associated with ocean travel. Two people could use the boat simulator at one time, and both visitors would be able to navigate through the ocean and view the right whales.

We developed this exhibit idea after examining a similar concept used in the “Thrill Ride 360°” exhibit at Museum of Science, Boston. This exhibit allows visitors to experience a roller coaster ride as they sit inside of a pod which physically tilts, moving to correspond with a roller coaster displayed on a screen inside the pod. Our exhibit utilizes a similar concept, with a focus on how the shipping and fishing industries affect North Atlantic right whales.

The characteristics that received a “+” rank were *physical design, interactive, immersive*, and *accommodates animals*. The physical design of this exhibit would be very welcoming, as it requires its own separate room. Visitor would be required to interact with this exhibit in order to use it, and it could be designed to be completely immersive. Therefore, this exhibit has a very strong holding power. Additionally, this exhibit would cause no harm to the animals in the surrounding exhibits.

"*Wow factor", multigenerational, focus on education,* and *easily navigated* were given a "0" rank. In this exhibit, the "wow factor" is that the visitor will be able to experience the right whale up close, but the boat simulator will not be able to convey the whale's size. This exhibit would allow for interaction between age groups, but it does not encourage it. Children are able to use this simulator without the help from their parents. Education is not the main focus of this exhibit, but it does encourage the visitor to pursue further learning. This exhibit is not the very easy to navigate. No prior knowledge of this piece of technology is required for use.

The characteristics *interpreter, price of hardware, space, upkeep,* and *durability* were given a " - " rank. This exhibit does not allow for the use of a NEAq interpreter, since you are enclosed completely within the simulator. The price range for this piece of technology would be $100,000 or more, based on estimates for military flight simulators. Mixed reality would most likely be the most expensive of the technologies we considered. Because this exhibit would be too large for any available space in the NEAq, additional space would be required. The upkeep would require a full-time employee to both maintain and run the exhibit. This exhibit is constantly in rigorous use, and therefore not very durable. Overall this exhibit has strong attracting and holding power, but weak communicating power. A full ranking of all characteristics for this exhibit can be found in Table 4.

Table 4. Characteristics of "Boat Simulator" exhibit.

Positive Characteristics(+)	Physical Design, Interactive, Immersive, Accommodates Animals
Neutral Characteristics(0)	"Wow Factor", Multigenerational, Focus on Education, Easily Navigated
Negative Characteristics(-)	Interpreter, Price of Hardware, Space, Upkeep, Durability

4.2.5. Touchscreens - Life Sized Whale

A Life-Sized North Atlantic right whale exhibit would feature a full scale replica of a right whale that visitors could walk through and around. Located around the right whale, visitors would find touchscreens providing more information on North Atlantic right whales and the NEAq's efforts to conserve the species. The inside of the whale would also be open for visitors to walk in, with more touch screens containing information geared towards younger visitors. We based our exhibit design on a similar interactive exhibit at the Institute for Contemporary Art. The exhibit allows visitors to enter a re-creation of a whale and examine various species of whale bones (Schreiber, L. 2013). Our exhibit attempts to recreate the interactivity of this exhibit through the use of touchscreens, while focusing exclusively on North Atlantic right whales.

The characteristics that earned a "+" rank on this exhibit were *"wow factor", physical design, immersive, easily navigated, price of hardware,* and *accommodates animals*. This exhibit would allow visitors to experience the "wow factor" of seeing this large animal up close, attracting the visitors' attention. The physical design of this exhibit would attract visitors with its adequate space and lighting. This exhibit would fully immerse visitors, focusing their attention on the whale model and touch screens. The technology used would not require any prior knowledge to operate, so the exhibit would be easily navigable. The price range for the touchscreen hardware is under $10,000, based on the price of consumer tablets (comparable to the iPad's currently in use around the penguin exhibit). Touch screen technology is also harmless to the animals in the surrounding exhibits.

The characteristics that received a "0" rank were *interactive, multigenerational, focus on education, interpreter, upkeep,* and *durability*. This exhibit would encourage visitors to further their learning, but it would not inherently be part of the exhibit. The visitors could interact with the touchscreens, but they could also choose to only observe the whale replica. Interaction between different age groups is not required. A staff interpreter would not necessarily be needed for this exhibit, but could accompany it to answer visitor questions. This exhibit would require near daily upkeep.

The characteristic that received a " - " rank was space. A life-size right whale is 45-60 feet long, meaning this exhibit would take up a significant amount of space. In order for the Aquarium to construct this exhibit, it would have to clear out a large area of exhibit space. Overall, this exhibit has strong attracting, holding, and communicating power. A full ranking of all characteristics for this exhibit can be found in Table 5.

Table 5. Characteristics of "Life Sized Whale" exhibit.

Positive Characteristics(+)	"Wow Factor", Physical Design, Immersive, Easily Navigated, Price of Hardware, Accommodates Animals
Neutral Characteristics(0)	Interactive, Multigenerational, Focus on Education, Interpreter, Upkeep, Durability
Negative Characteristics(-)	Space

4.2.6. Touchscreens - Interactive Video

An interactive video exhibit would consist of a touchscreen kiosk that allows visitors to play out a short story and make their own decisions to see the effects on a North Atlantic right whale in its natural habitat. The purpose of this exhibit is to show how humans and their choices can directly impact North Atlantic right whales. The exhibit would utilize a combination of live action video and computer generated animations. We developed this exhibit through inspiration from two sources: a previous Major Qualifying Project, titled “The Urban Whale”, which developed an interactive video game focused on spreading awareness about the North Atlantic right whale as an endangered species, and the Turtle Rescue exhibit, currently on display in the NEAq. “The Urban Whale” video game uses computer generated graphics to establish a connection between the player and the whale (Bryant, Bujnevicie, Petersen, Prueitt. Racine, 2015). Similarly, our exhibit idea would establish a similar connection in the same manner, using computer generated images. The Turtle Rescue exhibit has a similar structure to our proposed exhibit idea, providing short video clips after the visitor interacts with the exhibit. In our exhibit, these interactions would consist of pressing a button to make a decision based on a presented scenario.

The characteristics that scored a “+” rank were *physical design*, *interactive*, *focus on education*, *easily navigated*, *price*, *space*, and *accommodates animals*. This exhibit would feature adequate light and space for a physical design that would attract visitors. This exhibit requires interaction for use, which would hold visitors’ attention. The exhibit focuses on education, and effectively informs the visitors about both North Atlantic right whales and the NEAq’s message of conservation. This exhibit requires no prior knowledge to operate and would be easily navigated. The price range of this technology hardware is under $10,000, based on prices of consumer tablets comparable to those currently in use at the NEAq. This exhibit could easily fit into space already available in the NEAq, so no additional construction would be required. In addition, touchscreens would not cause any harm to the animals in the surrounding exhibits.

The characteristics that received a “0” rank were *immersive*, *multigenerational*, *upkeep*, and *durability*. This exhibit is not entirely immersive and could allow visitors to become distracted by their surroundings. This exhibit would allow for interaction between age groups, but does not encourage it, making it only partially multigenerational. Daily upkeep would be required for this exhibit, and its durability would depend on the amount of visitor interaction.

“Wow factor” and *interpreter* received a “ - ” rank for this exhibit. The full size of a North Atlantic right whale would not be conveyed to visitors in a way that truly allows them to experience it. An interpreter is also not required for this exhibit, because the video would provide all of the information to the visitor. Overall, this exhibit has strong attracting, holding, and communication power. A full ranking of all characteristics for this exhibit can be found in Table 6.

Table 6. Characteristics of “Interactive Video” exhibit

Positive Characteristics(+)	Physical Design, Interactive, Focus on Education, Easily Navigated, Price, Space, Accommodates Animals
Neutral Characteristics(0)	Immersive, Multigenerational, Upkeep, Durability
Negative Characteristics(-)	“Wow factor”, Interpreter

4.2.7. Projection Mapping - Swimming North Atlantic Right Whale

In this exhibit, a North Atlantic right whale would be projected onto the walls of the NEAq, as if it were swimming through the aquarium. By projecting a whale swimming along the walls within the New England Aquarium, visitors would develop a sense of the size of the whale and how it moves. We again used the Sumida Aquarium exhibit as inspiration for this exhibit ("Water tank projection mapping…", 2015).

The characteristics that scored a "+" rank were *"wow factor", physical design, easily navigated,* and *durability*. The "wow factor" would be conveyed through the full scale, whale projection, attracting visitors to the exhibit. This exhibit would have adequate space and lighting, and would be clearly visible to the visitors within the Aquarium. The design of this exhibit would create a strong attracting power. The visitors would be able to easily navigate this exhibit, since the technology being used requires no prior knowledge to operate. As visitors do not directly interact with the projector, this exhibit would be highly durable.

For this exhibit, a "0" rank was given for the characteristics *immersive, multigenerational, interpreter, price of hardware, space, upkeep,* and *accommodates animals*. This exhibit is not fully immersive, as visitors could still be aware of surrounding exhibits. The design of this exhibit, but not encourage, multigenerational interactions. Therefore, this exhibit would be partially multigenerational. An interpreter would not necessarily be required for this exhibit. The price range for the projector would be around $10,000-$100,000, based on the cost of a high-quality projector. This exhibit would only require wall space, so the Aquarium would not have to clear a large amount of space for this exhibit. However, they would also need to create space for the projector and make certain other exhibits do not block the projections, as well as ensure other live exhibits are unaffected by the projector. This exhibit would require daily upkeep.

Interactive and *focus on education* earned a " - " rank for this exhibit. This exhibit would not allow for any interaction between the visitors and the technology. There would be no emphasis on education, since the only information being conveyed to the visitors directly is the size of the whale. Overall, this exhibit has strong attracting power, but little holding or communicating power. A full ranking of all characteristics for this exhibit can be found in Table 7.

Table 7. Characteristics of "Swimming North Atlantic Right Whale" exhibit.

Positive Characteristics(+)	"Wow Factor", Physical Design, Easily Navigated, Durability
Neutral Characteristics(0)	Immersive, Multigenerational, Interpreter, Price of Hardware, Space, Upkeep, Accommodates Animals
Negative Characteristics(-)	Interactive, Focus on Education

4.2.8. Projection Mapping - North Atlantic Right Whale

This exhibit would consist two different North Atlantic right whale projections onto an artificial skin, which would either be overlaid on the already in place right whale skeleton. The first projection would be an example of a “healthy” right whale, free from scarring. The second projection would be of a whale with heavy scarring, injured by a ship strike or fishing line entanglement. The point of this exhibit would be to illustrate the impact humans have on right whales, particularly mariners. This exhibit design works similarly to the proposed phone application, in that information is displayed “over” the existing whale skeleton. This time, however, the display is done in the real world, without the use of a smartphone.

This is similar to the projection mapping exhibit presented in 4.2.7, however differs primarily in the fact that the whale would be in a fixed location. Also, this exhibit would be projected onto a three-dimensional object, whereas the previous exhibit would more than likely be projected on a flat surface. This is also similar to the Augmented Reality exhibit, in that it adds a “skin” to the whale skeleton. The key difference between the app and this exhibit, however, is that no additional devices, such as a smartphone, are required by the visitors to experience the projection mapped exhibit. The augmented reality exhibit could also provide text-based information about the whales directly in the app, whereas the projection exhibit would need additional signage.

The characteristics that received a “+” rank were *“wow factor”, physical design, easily navigated, interpreter,* and *durability*. The “wow factor” would be achieved by showcasing the large size of this animal and allowing visitors to get up close to the projection of the whale, and thus attracting the visitors. The physical design would also attract the visitors’ attention due to its large size and the light it produces. This exhibit would be easily navigated by the visitors as it would not require any prior knowledge to use. There would not be much information on display, so an interpreter would be needed to tell the visitors about the right whale and answer any questions the visitors may have. This exhibit would be very durable due to no direct visitor interaction with the projector, therefore no risk of damage to the equipment.

A “0” rank was given to *immersive, multigenerational, focus on education, price of hardware, space, upkeep,* and *accommodates animals*. The design of this exhibit would allow for the visitors to notice surrounding exhibits, so they would not be fully immersed in this exhibit. Interaction between age groups would be allowed by the design of this exhibit, but interaction would not be encouraged. This exhibit would show visitors the threats the right whale faces, but it would not explicitly say what they are. Therefore, this exhibit would not completely get across the message the NEAq wants to portray to the visitor about the visitors. This exhibit would not directly inform the visitors about the NEAq message, but it does encourage them to pursue further learning. The price range for the hardware to operate this exhibit would be between $10,000 and $100,000, based on the cost of a high-quality projector. This exhibit could easily be constrained to fit in an available space with the NEAq, so additional space would not have to be constructed to implement the exhibit. The upkeep of this exhibit would require daily maintenance, and the projector must be used in a way that would not harm the animals in surrounding exhibits.

A " - " rank was given to *interactive*. No interaction is required between the visitors and the exhibit. This exhibit can easily attract and hold visitors, however the communication power is possibly lacking because visitors may not realize the reason for the difference between the two different projections. If they do not realize that humans are the cause of harm to the second whale, the whole message of the exhibit is lost. Additionally, due to the graphic nature of the injuries right whales sustain, this exhibit may prove to be too graphic to implement. A full ranking of all characteristics for this exhibit can be found in Table 8.

Table 8. Characteristics of "North Atlantic Right Whale" exhibit.

Positive Characteristics(+)	"Wow Factor", Physical Design, Easily Navigated, Interpreter, Durability
Neutral Characteristics(0)	Immersive, Multigenerational, Focus on Education, Price of hardware, Space, Upkeep, and Accommodates Animals
Negative Characteristics(-)	Interactive

4.2.9. Projection Mapping - "Live" Show

This exhibit would consist of a large stage, similar to the one currently in use for seal and sea lion shows. Then projection mapping would be used to allow North Atlantic right whales to interact and perform in a style similar to the sea lion show. There would be human performers as well, who would convey the desired information to the audience. We developed this exhibit idea as we attempted to recreate the experience of seeing a show with live animals, such as the sea lions at the NEAq, through emerging technology.

This exhibit scored a "+" rank in *"wow factor", physical design, immersive, focus on education, easily navigated, interpreter,* and *durability*. The large size of the animal being conveyed and the ability for the visitor to get up close would create the "wow factor". The physical design of this exhibit would use adequate lighting and space to attract an audience. The "wow factor" and physical design together could produce a very strong attracting power. This exhibit would totally immerse the crowd, since their attention would solely be on the exhibit. This exhibit would be closed off from the other exhibits, so the visitors would not get distracted by other exhibits. This separation could hold their attention. There would be a large emphasis on education in this exhibit. This show would not only show the visitors how the whale behaves and interacts, but also the dangers they face due to human activity. This exhibit would also be easily navigated, because the visitor would not need any prior knowledge to interact with this technology. The interpreters would be there to explain to the visitors the dangers the whales face and what they could do to help, and also answer any additional questions they may have. These factors combined create a powerful communicating power. The durability of this exhibit would be high, since the visitors could not directly interact with the exhibit. Therefore, there would be no risk of damage to the projector.

The characteristics that received a “0” rank for this exhibit were *interactive, multigenerational, price of hardware, upkeep,* and *accommodates animals*. The piece of technology required does not require the visitors to interact with it. However, the visitors could interact with the interpreter if they so choose. Different age groups would not be required to interact with each other to enjoy the exhibit, so the exhibit would be considered partially multigenerational. The price range for the projector would be between $10,000 and $100,000, based on the cost of a high quality projector. The upkeep of this exhibit would require daily maintenance, and the projector must be used in a way that it would not harm the animals in surrounding exhibits.

Space received a “ - ” rank for this exhibit because the exhibit would require a very large area be set aside within the NEAq. Overall, this exhibit has very strong attracting, holding and communicating power. A full ranking of all characteristics for this exhibit can be found in Table 9.

Table 9. Characteristics of “‘Live’ Show” exhibit.

Positive Characteristics(+)	“Wow Factor, Physical Design, Immersive, Focus on Education, Easily Navigated, Interpreter, Durability
Neutral Characteristics(0)	Interactive, Multigenerational, Price of Hardware, Upkeep, Accommodates Animals
Negative Characteristics(-)	Space

4.3. Discussion of Matrix

We consolidated Table 1 through Table 9 into our complete matrix, which we used to conduct our analysis. This matrix is provided in Figure 16. The five technologies we focused our research on are listed along the vertical axis: virtual reality, augmented reality, mixed reality, touch screens, and projection mapping. A second column along the vertical axis lists the nine exhibit ideas discussed throughout section 4.2 alongside the emerging technology featured most prominently. The horizontal axis outlines the thirteen characteristics with which we evaluated each exhibit idea. These characteristics are organized into attracting power, holding power, communicating power, or limitations, depending on which power the characteristic relates to most strongly. To allow for easier viewing, positive (“+”) rankings are denoted by a green box, neutral (“0”) rankings are denoted by a yellow box, and negative (“-”) rankings are denoted by a red box.

Figure 17 outlines our specific criteria used to determine an exhibit’s score for each characteristic. These rankings needed to be developed independently for each characteristic in order to ensure that our rankings were as quantitative as possible. Initially, we had developed a more general ranking guide to be applied to all the characteristics. After some analysis, we determined that this method resulted in data that was too qualitative to be of much value in our final results.

Overall, our matrix, combined with the key explaining our ranking system, will allow readers to scan through our exhibit ideas and compare them in terms of the defined characteristics.

Table 10. Technology Comparison Matrix Based Upon Sample Example Exhibits

		Attracting Power		Holding Power		Communicating Power				Limitations				
Technology	**Exhibit Ideas**	**"Wow Factor"**	**Physical Design**	**Interactive**	**Immersive**	**Multi-generational**	**Focus on Education**	**Easily Navigated**	**Interpreter**	**Price of Hardware**	**Space**	**Upkeep**	**Accommodates Animals**	**Durability**
Virtual Reality	Use virtual reality to allow visitors to "swim" with the whales and experience a day in their life.	+	-	+	+	-	-	-	-	+	+	-	+	-
Augmented Reality	Design an app that works with the aquarium to "bring the building to life" with a whale skin overlaid on the skeleton that can be tapped for more information.	+	-	+	0	+	+	0	-	+	+	+	+	+
	Display digital whales (and other aquatic life) in the tanks that allow visitors to "talk to" and learn from the animals.	+	+	0	0	0	+	+	0	0	+	+	0	+
Mixed Reality	Similar to a flight simulator, by captaining a cargo boat or fishing vessal in North Atlantic right whale territory.	0	+	+	+	0	0	0	-	-	-	-	+	-
Touch Screens	Construct a life-sized North Atlantic right whale for visitors to walk in/around, with touch screens and videos to supplement information.	+	+	0	+	0	0	+	0	+	-	0	+	0
	Interactive video where visitors make their own decisions to see how they impact North Atlantic right whales.	-	+	+	0	0	+	+	-	+	+	0	+	0
Projection Mapping	Project a life-sized North Atlantic right whale to swim around the aquarium walls.	+	+	-	0	0	-	+	0	0	0	0	0	+
	Project a healthy North Atlantic right whale, and then a NARW affected by ship strike or fishing line entanglement.	+	+	-	0	0	0	+	+	0	0	0	0	+
	A "live" show featuring a projected whale and live human interpreter to discuss whales and answer visitor questions (similar to seal show).	+	+	0	+	0	+	+	+	0	-	0	0	+

Table 11. Matrix Criteria Key

	-	0	+
"Wow Factor"	Does not convey the size of the whales or allow visitors to get up close	Either conveys the size OR allows visitors to get up close	Conveys the size of the whales and allows visitors to get up close
Physical Design	Lack of adequate space and lighting	Includes adequate space OR lighting	Includes adequate space and lighting
Interactive	Doesn't allow for visitor interaction	Allows for visitor interaction, not required	Visitor interaction is required
Immersive	Visitor attention not dedicated to exhibit	still being aware of his or her surroundings	Visitor attention must be solely devoted to exhibit
Multigenerational	Doesn't allow for interaction between age groups	Allows for interaction between age groups	Encourages interaction between age groups
Focus on Education	Exhibit does not inform visitors about NEAq message	Exhibit encourages visitor to pursue further learning	Exhibit informs visitors about NEAq message
Easily Navigated	Prior knowledge of the technology required	Prior knowledge of the technology is helpful but not required	No prior knowledge of the technology is required
Interpreter	Doesn't allow for NEAq interpreter	Allows for NEAq interpreter	Encourages NEAq interpreter/Necessary for exhibit
Price of Hardware	Over $100,000	$10,000 - $100,000	Under $10,000
Space	Requires new space	Can be constrained to fit in avalible space	Can easily fit in space already avalible
Upkeep	Requires full-time employee	Requires maintenance/work as often as daily	Does not require regular work
Accommodates Animals	Not suitable for use around animals	Modifications may need to be made in order to accommodate animals	No risk to animals
Durability	Encourages prolonged interaction	Low visitor interaction, but high risk of regular wear and tear	No direct visitor interaction, so no risk of damage

5. Conclusions

We developed nine proposed exhibit ideas that relate to the characteristics determined through our research to represent an effective, technology-based exhibit. This matrix, seen in Figure 16, provides the NEAq with an idea of how emerging technologies could be applied through new exhibits within the aquarium, and how successful these exhibit ideas would be in attracting visitors, holding visitors' attention, and effectively communicating the NEAq message to visitors. Additionally, it evaluates the limitations of these exhibits. As the NEAq moves forward with implementing an exhibit utilizing emerging technologies to educate, this information can be valuable to the NEAq moving forward if they hope to one day implement an exhibit utilizing emerging technologies to educate the public on the dangers facing North Atlantic right whales.

5.1. Analysis of Findings

After analyzing the patterns in our matrix, we found the majority of these technologies possess the characteristics "wow factor", physical design, multigenerational, easily navigated, and accommodates animals. The "wow factor" and physical design allow visitors to get up close and experience the large size of the right whale in an area with adequate space and lighting. Together, these characteristics indicate that most of the technologies possess a strong attracting power. Although most of these technologies do not encourage multigenerational use, they do still allow for it. Therefore, visitors from different age groups could still interact and experience the technologies together. Most of these technologies were found to be easily navigated, allowing the visitors to use the technology without prior knowledge of how it works. Easy navigation also means that visitors would not feel intimidated by the technology and would be able to easily interact with it. In addition, all of the technologies would safely accommodate the animals within the aquarium.

We then analyzed each individual type of technology, and found trends in the characteristics they incorporate. Virtual reality tends to effectively hold the visitors' attention, but does not effectively communicate the NEAq message to visitors. The virtual reality goggles allow visitors to become completely immersed in the exhibit, and require the visitors to interact with this virtual world. Although this exhibit easily holds the attention of the visitors, it is not able to effectively convey information to the visitors. Virtual reality is not easily navigated and does not focus on education, encourage interaction between visitors, or allow for a staff interpreter. Therefore, virtual reality has no communicating power.

Augmented reality requires the least amount of resources. It was ranked well for price of hardware, space, upkeep, accommodates animals, and durability. Both of the augmented reality exhibits use hardware that would cost very little for the NEAq to implement. The additional space needed for this type of technology would be minimal, because the technology can easily be incorporated into exhibits already on display at the NEAq. For example, our smartphone application uses the right whale skeleton that is already hanging in the aquarium. The upkeep of augmented reality would be minimal, since it does not require regular work and tends to function properly for a long periods of time with little maintenance. The smartphone, for example, would only need to have the software updated when needed. Augmented reality does not require direct interaction with the visitors, so there will be no risk of damage.

Mixed reality effectively holds the attention of the visitors, but does not communicate the NEAq message well. This type of technology allows for the visitor to become immersed in another world, and have the visitor's focus solely devoted to the exhibit. The mixed reality exhibit also requires interaction for the visitor to use this technology. Therefore, mixed reality has strong holding power. The characteristics mixed reality did not score positively on are multigeneration, focus on education, need for an interpreter, and easily navigated. This technology does not require interaction between the visitors or an interpreter. Mixed reality is not easy to use without any prior knowledge, so it may detract from visitors' experience and distract them from the main message of the exhibit. The focus of this exhibit may not be on education, and the NEAq message will not be transferred to the visitors. In conclusion, mixed reality does not have a strong communicating power.

Projection mapping has strong attracting power, but lacks holding power. The projections of the whale will allow the visitors to get up close to the whale and experience its large size. The adequate space and lighting also creates a pleasant physical design. The "wow factor" and physical design creates a strong attracting power for projection mapping. The holding power is weak, because projection mapping is generally neither immersive nor interactive. While observing the projections, the visitors would still be able to view surrounding exhibits. Therefore, their attention would not be solely devoted to the projection mapping. In addition, it is not possible for the visitors to interact with the projections.

In conclusion, each type of technology has its strong points and weaknesses. The observation made here were about the specific type of technology as a whole, but from the matrix (Figure 16), it can be observed that the way the technology is used can affect which characteristics are present in that exhibit. Therefore, technology is a very useful tool in creating exhibits.

5.2. Limitations of our Project

While we worked to develop the most complete project we could, there were limitations to our project. First, we were only able to conduct interviews at two facilities around the Boston area. We did reach out to several other facilities outside New England, but never received a response from them. The additional facilities we reached out to both utilize innovative technology, and we determined through a preliminary web search that they could provide us with valuable information to further our analysis. Specifically, this information could have could have given us an insight into how these technologies were implemented at each facility and what visitor feedback has been on the exhibits so far. More interviews in general would have simply provided us with more information to support our claims, and resulted in a more thorough analysis.

Second, due to procedures at the NEAq, we were unable to conduct visitor interviews. However, the NEAq did supply us with their most recent visitor data. While these data were sufficient to inform our project, conducting interviews with visitors would have added even more valuable information to our report. For example, we could have asked visitors directly about their opinions on current examples of how emerging technology is being implemented. Their responses would have provided a different perspective on the exhibits and technology- one that is free from ideas about the *intended* purpose of exhibits. Visitors, unaware of specifically what the NEAq's intended goals are, must infer for themselves the purpose of exhibits. If visitors are able to tell us the purpose, the exhibit in question would do a good job of communicating that to visitors and characteristics of that exhibit would be beneficial to represent in our designs.

Finally, we were unable to accurately estimate certain limitations, including cost, space, and upkeep. The information we have included in our findings are very rough estimates. An accurate cost or space estimate would require a more complete exhibit design idea. Because our project was focused on developing concepts for exhibits that could utilize technology to educate the public on the dangers facing the North Atlantic right whale, it was not necessary to determine the exact parameters of the exhibits. For our cost estimates, we considered only the cost of one piece of hardware- for example, our estimate for the cost of a virtual reality exhibit was based on the cost of one Oculus Rift headset. This means that the cost of software and labor (to develop the program that will run in the exhibit and allow visitors to "swim" with the whales), as well as the cost of multiple headsets (given that, most likely, an exhibit would feature more than one headset to accommodate crowds, and perhaps spares to accommodate breakages), were not considered, but are crucial to a thorough cost analysis. We are not in a position to determine or estimate labor costs.

5.3. Recommendations for Moving Forward

Moving forward, the NEAq could select one of our exhibit design ideas to develop further, or further develop another exhibit idea using one of the identified emerging technologies. The NEAq could also continue to use our developed method to continue to analyze future emerging technologies.

First, one of our exhibit ideas could be selected by the NEAq to be developed into an actual exhibit. The NEAq could determine specific traits they wish to apply to the exhibit, and select an exhibit idea based on these traits. To do this, the NEAq could use our exhibit comparison matrix, and select an exhibit that best fits their goals for the exhibit. The next steps of exhibit design would then take place, involving a more detailed sketch of our idea that would include measurements and exact quantities of technologies being used (for example, the number of virtual reality headsets needed for the Swim with the Whales exhibit or the number of touch screens that would be needed to supplement the life-size North Atlantic right whale model).

Once the required space and quantities are known, the cost to implement an exhibit can be more fully developed. From there, the aquarium can move forward with clearing out a space for the exhibit and constructing it.

A second option would be to use one of our ideas as inspiration for a new, but related exhibit idea. Given our analysis, the NEAq could combine or alter some of our ideas into one they feel better addresses the characteristics that are more important for them to include.

The NEAq could also simply use our criteria to analyze future ideas they may develop for exhibits. We have established a set of characteristics that are important to effective exhibits, as well as a general ranking system that illustrates how these characteristics should be analyzed. This ranking system allows the NEAq to evaluate any ideas they develop based on the characteristics we determined as important through our research.

5.4. Importance of a Right Whale Exhibit

A North Atlantic right whale exhibit would be an important addition to the NEAq. A right whale exhibit can be used to educate the public about whales themselves. Our interview with a whale watch guide informed us that most of the questions attendees ask while aboard a whale watch are about basic whale facts, indicating a public desire to learn about whales, and therefore, North Atlantic right whales.

According to interviewed NEAq employees, in addition to providing information on the whales themselves, a right whale exhibit must also showcase the NEAq's current efforts to research and protect North Atlantic right whales. As home to the longest running North Atlantic right whale research program in the world, the NEAq has a lot of information to provide to the public about their efforts. The NEAq has been an important part of many actions taken to protect North Atlantic right whales. They have helped tag and track the behaviors of many North Atlantic right whales through GIS, which led to an informed redirection of shipping lanes. These actions are important, and should be shared with NEAq visitors as they add another level to exhibits instead of simply focusing on basic facts that could be found through internet research.

Finally, having learned about North Atlantic right whales and how few of them are left in the wild, and after becoming informed on all the efforts being taken by the NEAq to protect this species, visitors could be inspired to take action themselves. Public support is crucial to successfully enacting and enforcing laws. Gaining public support in this case could begin to increase the population of North Atlantic right whales, and hopefully save the species from extinction.

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Appendix A: Interview Questions for New England Aquarium Employee A

1. What does your job entail?
2. Are there any common features/factors between the most popular exhibits?
3. How do inanimate exhibits compare to live exhibits as far as visitor reception is concerned? Do they attract a similar number of visitors? Do they hold visitors attention equally?
4. Are there any common features/factors among these inanimate exhibits that make them more popular among visitors than other exhibits in their category?
5. Do you think that inanimate or live exhibits are more effective at communicating a message to visitors? Why?
6. What are your personal goals when developing/reviewing an exhibit?
7. Which exhibits at the NEAq do you think do an exceptional job at accomplishing these goals?
8. Additional information on exhibits? Specifically, number of visitors per exhibit and how long visitors stay at exhibits.
9. Who do you suggest meeting with/conducting interviews with next? Connections with other museums/aquariums?

Appendix B: Interview Questions for New England Aquarium Employee B

Introductory Questions:

1. What is your name and position at the Aquarium?
2. What does your job entail?
3. How long have you been working here?

Question Set 1:

1. What do you think are the main goals of a NEAq exhibit?
2. Which exhibits at the NEAq do you think do an exceptional job at accomplishing these goals?

Question Set 2:

1. Are there any common features/factors between the most popular exhibits?
2. How do inanimate exhibits compare to live exhibits as far as visitor reception is concerned? Do they attract a similar number of visitors? Do they hold visitors attention equally?
3. Which inanimate exhibits are more popular than other inanimate exhibits?
4. Are there any common features/factors among these inanimate exhibits that make them more popular among visitors than other exhibits in their category?
5. [Assuming the interviewee has talked mostly positively about live exhibits]: Do you think that live exhibits are superior to their inanimate counterparts? Why?
6. [Assuming the interviewee has talked mostly positively about inanimate exhibits]: Do you think that inanimate exhibits are superior to their live counterparts? Why?
7. Do you think that inanimate or live exhibits are more effective at communicating a message to visitors? Why?

Question Set 3:

1. What exhibits have you worked on at the NEAq?
2. What process do you go through when designing an exhibit?
3. [Ask him to expand on exhibit he’s worked on]

Appendix C: Interview Questions for New England Aquarium Employee C

*Please note that these questions have been edited for confidentiality reasons.

Introductory Questions:

1. What is your name and position at the Aquarium?
2. What does your job entail?
3. How long have you been working here?

Question Set 1:

1. We talked to [NEAq Employee A] about some of the issues that come with using technology on such a large scale as the NEAq, can you tell us about some of the issues you have to deal with?
2. Problems are always going to occur when technology is in use, but have you encountered any exhibits that had more problems than they were worth?
3. Is there technology that just does not work in the NEAq setting, whether it be due to a high learning curve or another reason?
4. What improvements do you think could be made to help technology in the NEAq run more smoothly?
5. Which aquarium exhibit do you think does a good job at utilizing technology?
6. How would you like to see technology integrated at the NEAq? Is there any technology you'd really love to see the NEAq find a use for?
7. Do you have a favorite exhibit you've worked on?
8. [NEAq Employee A] mentioned that you had recently worked with someone at [another museum facility]. We were wondering who, and if you would be able to put us in contact with them?

Appendix D: Interview Questions for Boston Harbor Cruises Whale Watch Employee A

1. What is the typical Boston Harbor Cruise whale watch visitor?
2. On average, how many whales are seen during a whale watch? What kind of whales? Have you ever seen a North Atlantic Right Whale?
3. What makes a “good” whale watch?
4. What information is the whale watch trying to convey to visitors? What does Boston Harbor Cruises hope visitors take away? What information is important for visitors to know about the whales, but can’t easily be conveyed during a whale watch setting?
5. What are common questions visitors ask?
6. Describe a memorable whale watch.

Appendix E: Interview Questions for [Name of Museum] Interview

*Please note that title and questions have been edited for confidentiality reasons.

Introductory Questions:

1. What is your name and position at the museum?
2. What does your job entail?
3. How long have you been working here?

Question Set 1:

1. What do you think are the main goals of a museum exhibit?
2. Which exhibits at the museum do you think do an exceptional job at accomplishing these goals?

Question Set 2:

1. Are there any common features/factors between the most popular exhibits?
2. Can you tell us about some of the issues you have to deal with concerning technology?
3. Problems are always going to occur when technology is in use, but have you encountered any exhibits that had more problems than they were worth?
4. Is there technology that just does not work in the museum setting, whether it be due to a high learning curve or another reason?
5. What improvements do you think could be made to help technology in the museum run more smoothly?
6. Which exhibit do you think does a good job at utilizing technology?
7. How would you like to see technology integrated at the museum? Is there any technology you'd really love to see the museum find a use for?
8. Do you have a favorite exhibit you've worked on?

Question Set 3:

1. What exhibits have you worked on at the museum?
2. What process do you go through when designing an exhibit?
3. [Ask them to expand on exhibit he's worked on]
4. We noticed the [name of specific exhibit]. Can you tell us more about it and its popularity?

Appendix F: List of Exhibit Characteristics

Characteristic	Definition	**Primary Power** Secondary power
"Wow Factor"	Anything exceptionally "large, cute, strange, or unusual"	**Attracting** Holding
Physical Design	Exhibit has adequate space/lighting	**Attracting**
Interactive	Allowing for visitor interaction	**Holding** Communicating
Immersive	Requiring visitor's dedicated attention	**Holding** Communicating
Multigenerational	Encouraging interaction between age groups	**Communicating**
Focus on Education	Informs visitors about NEAq message	**Communicating**
Interpreter	Staff at NEAq to further explain exhibit concepts to visitors	**Communicating** Holding
Price of Hardware	The cost of hardware required for the exhibit	**Limitations**
Space	Physical area required for an exhibit	**Limitations**
Upkeep	Frequency of regular repairs	**Limitations**
Animal Accommodation	Health risk to animals posed by exhibit	**Limitations**
Durability	Ability of exhibit to resist hardware failure	**Limitations**

Appendix G:

New England Aquarium Visitor Survey – Summer 2015 – Morey Group

Exhibits

Figure 24A

EXCELLENT RATINGS OF EXHIBITS

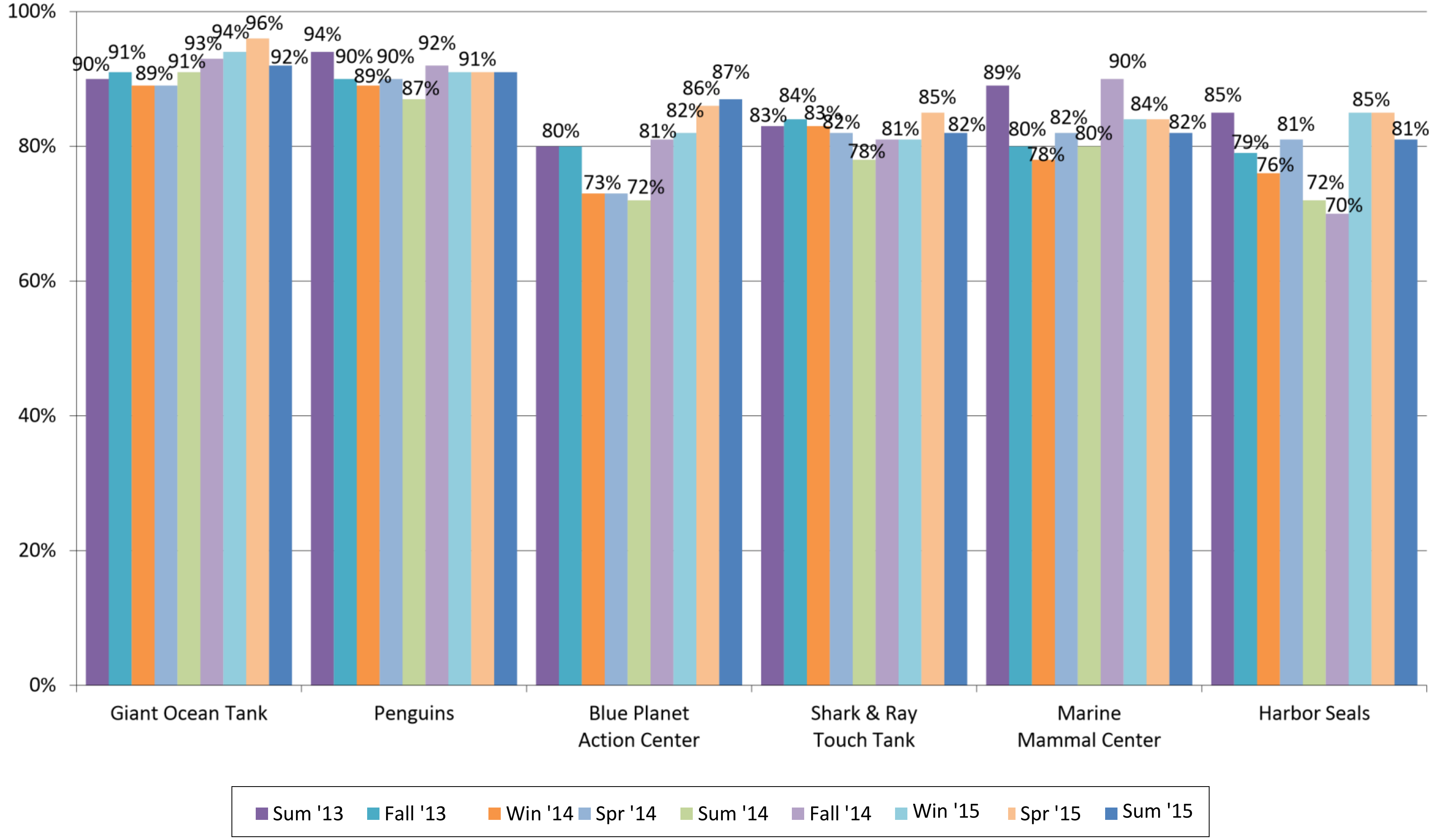
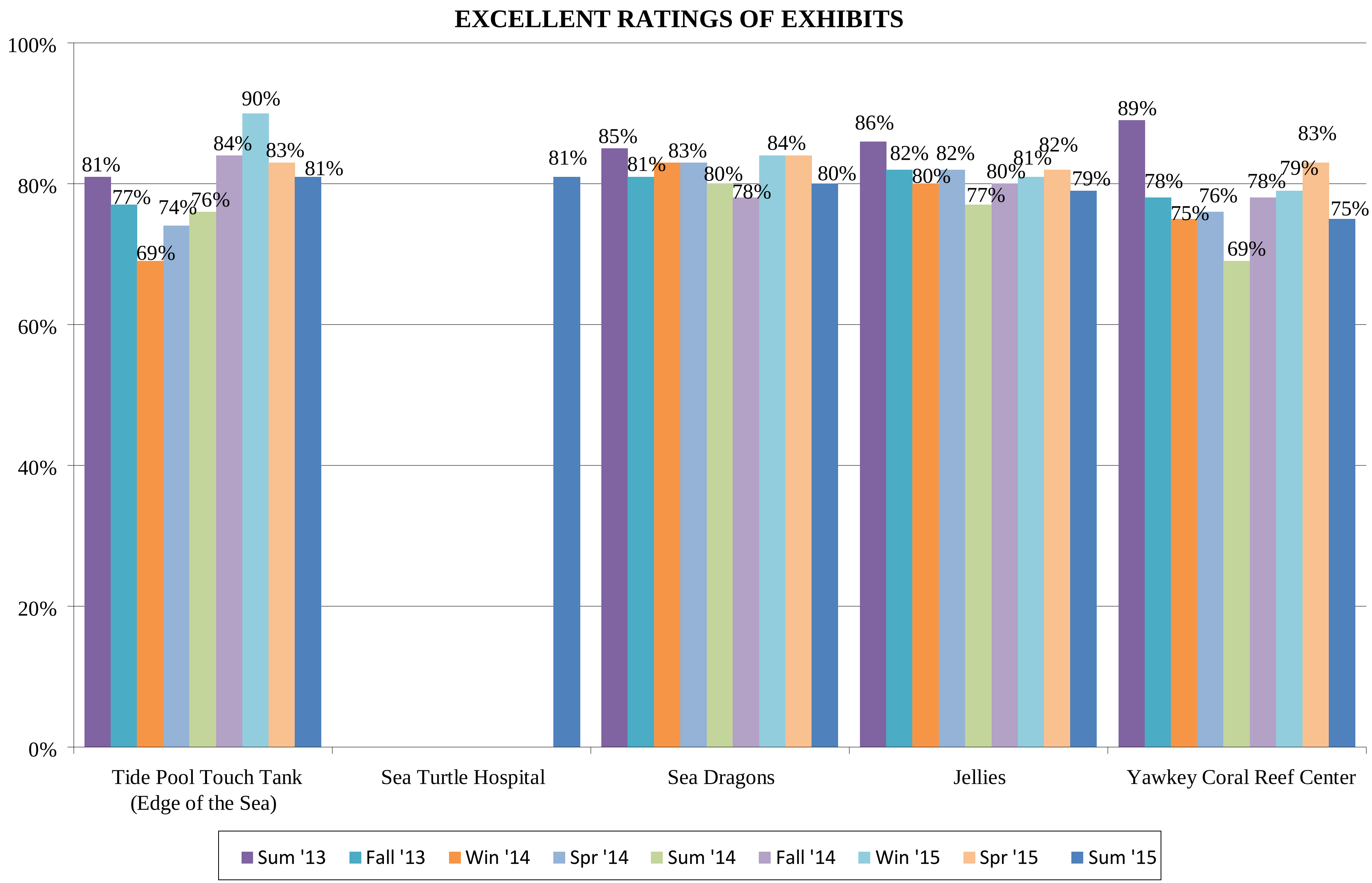


Figure 24B


EXCELLENT RATINGS OF EXHIBITS
100%
80%
60%
40%
20%
0%
81%
77%
69%
74%
76%
84%
90%
83%
81%
81%
85%
81%
83%
80%
78%
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80%
82%
77%
80%
81%
82%
79%
89%
78%
75%
76%
69%
78%
79%
83%
75%
Tide Pool Touch Tank (Edge of the Sea)
Sea Turtle Hospital
Sea Dragons
Jellies
Yawkey Coral Reef Center
Sum '13
Fall '13
Win '14
Spr '14
Sum '14
Fall '14
Win '15
Spr '15
Sum '15

Appendix H: Summative Team Assessment

Throughout the course of this project, our team was able to work well together. We delegated tasks to assign specific work to each group member, allowing for everyone to have something they could be doing. For example, we each were given a topic to focus on in both our writing and our presentations, and we were able to align these topics with group members' interests. Writing and speaking about topics that interested us made the process more enjoyable.

We also always treated each other with respect. All group members felt comfortable sharing their opinions, and we actively tried to maintain a positive work environment. Whenever a disagreement arose, those involved explained themselves and their reasoning and other group members listened to them and respected their ideas. We were able to work through any issues we encountered. The strongest example of this would be in using our matrix to analyze exhibit ideas. If the group did not agree on the rank a particular exhibit should receive, we each discussed the reasoning behind our rankings until we came to a consensus on what rank an exhibit should receive.

At all times our group was dedicated to this project. The IQP was always the top priority of all group members. We were willing to put in the extra time when necessary, sometimes working way past the expected 9-5 work hours.

Our group was always able to communicate well. In person, we always had an equal voice. When we were not together, we stayed in contact with emails and group messages. While these electronic communications were not always strictly project related, they were still highly effective. We were always quick to respond to each other, and this helped us with quick turnaround times.

One of the major challenges that our group experienced was sharing speaking time during meetings. This started off with some group members simply being more introverted than others. Over time, we worked to improve this inequality, eventually coming to a near equal share of meeting speaking time.

The other major challenge our team faced was staying focused and on-topic. While we did go off topic more than desired, our tangents did not affect the quality of our work. As previously mentioned, we put in the extra work where necessary in order to compensate and produce the best project possible.

Overall, our primary strategy for completing this project successfully, effectively, and on-time was sharing. We delegated tasks to split up the workload. We also split up speaking points in presentations, Finally, we were able to work out a way of dividing discussion points during meetings to allow for equal speaking time.