

Making the Old Mill New

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Abstract

The Nantucket Historical Association (NHA) wants to use interactive exhibits to improve their visitor experience. The goal of our project was to design, build, and refine interactive exhibits and interpretive materials for one of their properties, the Old Mill. We made four portable physical interactives, explored the STEM concepts of friction, levers, translation of motion, and energy conversion, all present in the Old Mill. Using an iterative design process, we improved our exhibit prototypes with feedback from the NHA and third graders, remaking one exhibit at a larger scale. We also made a storyboard for a digital exhibit about the Old Mill for learning and accessibility, using video of the Old Mill in action, a rendering of the Old Mill we made, and NHA staff interviews we conducted.

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Executive Summary

Introduction:

While museums worldwide attract hundreds of millions of visitors annually, they must continually work to improve visitation and the visitor experience. The Nantucket Historical Association (NHA) is trying to use interactive exhibits to improve the visitor experience at one of their properties, the Old Mill. Their goal is to make the Old Mill a must-see destination on Nantucket, and for it to be a model for other historic mills nationwide.

Project Objectives:

The goal of our project was to design, build, and refine a set of interactive exhibits and associated interpretive materials for the Old Mill. To complete this goal, the following project objectives were fulfilled by the project team:

1. Determined best practices in the design and evaluation of interactive museum exhibits.
2. Evaluated the interactive exhibits developed for the Old Mill in 2018, and developed design criteria.
3. Designed, tested, and built new and revised interactives for the Old Mill.

Our main tasks on Nantucket focused on the evaluation of previous exhibits and construction of new and revised exhibits. Based on interviews and background research, the team evaluated the previous exhibits used at the Old Mill. We then used iterative feedback from the NHA and third graders at Nantucket Intermediate School to build and improve our own exhibit prototypes.

The finalized prototypes were presented to the NHA to be used at the Old Mill or in the Whaling Museum. We also left recommendations for improvements that could be made for future iterations of our exhibits.

Project Outcomes:

The intended outcome of this project was to provide the NHA with interactive exhibits that could be used to provide learning opportunities and accessibility for the Old Mill. To accomplish this, we used an iterative design process to design, build, and improve upon our exhibits. Starting with cardboard mockups, we progressed to 3D renderings and plywood models for four physical exhibits. The first physical exhibit we completed was Grinding to a Halt, which teaches about friction and braking in the Old Mill. Next, we built a remake of an exhibit made by a previous WPI project team. This exhibit, called the Box O' Rocks, uses a lever arm to teach

about the Old Mill's static brake, levers, and forces. The next exhibit that we built was the Gearbox, which demonstrates translation of motion and inertia by modelling the gears in the mill. Finally, we built Turning on the Light, an exhibit that relates windmills to wind turbines by showing conversion from mechanical to electrical energy. We improved these exhibits with feedback from the NHA and the third grade classes at the Nantucket Intermediate School. Based on the feedback from students and the NHA, we made a larger version of our Box O' Rocks exhibit and improved our other exhibits. See Figures ES1 to ES5 below for images of all our finished exhibits.



Figure ES1: Grinding to a Halt Exhibit



Figure ES2: Box O' Rocks Exhibit



Figure ES3: Grinding to a Halt Exhibit



Figure ES4: Turning on the Light Exhibit



Figure ES5: Large Scale Box O' Rocks Exhibit

While we were making our physical exhibits, our group also assembled content for a digital interactive with the intent that it would improve accessibility for the Old Mill site and help bring the Old Mill to life. For footage, we conducted seven interviews with NHA staff, recorded the Old Mill in operation, and made animations of a 3D model of the Old Mill in motion. Using our footage, we made edited clips describing the parts and history of the Old Mill. We sent our animations of our model of the Old Mill and edited clips to Novation Media to be assembled into a digital exhibit.

Conclusions and Recommendations:

From our visit with the third graders, we conclude that our interactive exhibits are engaging to a younger audience. We also conclude that the exhibits appear to be effective at conveying the STEM concepts of friction, forces, levers, translation of motion, inertia, and energy conversion. We conclude that the interactives will enable the NHA to extend the learning opportunities presented by the Old Mill.

For Grinding to a Halt, we recommend that the NHA add interchangeable wheels of different sizes and with different materials on their exteriors. For our smaller Box O' Rocks, we recommend that the NHA add a pneumatic brake and replace the S-hooks with carabiners. For the Gearbox, we recommend that the NHA adds a funnel for collecting corn dropped off the

grindstone. For Turning on the Light, we recommend that the light be made easier to see. To accomplish this, we recommend adding more gears to the gear train, making it easier to turn on the light. We recommend that, as planned, Novation Media use our edited clips and storyboard to create a digital interactive exhibit.

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1. Introduction

Museums are popular and respected informal learning settings that positively impact local communities. While museums worldwide attract hundreds of millions of visitors annually, they must continually work to improve visitation and the visitor experience. As of 2017, the rate of replacement for historical museum visitors was 0.951 new visitors for every visitor lost (Schnieder, 2017). One of the ways that museums have worked to improve over time has been by changing how information is presented to museum goers. Museums are now intending to make visitors an active part of the learning process by changing exhibit designs (Hooper-Greenhill, 2000; Black, 2005). Interactive exhibits have been shown by several studies to improve visitor enjoyment over static exhibits, especially for children (Allen and Gutwill, 2004; Shaby, Assaraf, and Tal, 2017; Zaharias, Michael, and Chrysanthou, 2013).

The Nantucket Historical Association (NHA) is one organization trying to use interactive exhibits to improve the visitor experience at one of their properties, the Old Mill. Their goal is to make the Old Mill a must-see destination on Nantucket, and for it to be a model for other historic mills nationwide. Previously, the NHA had interactive exhibits made for the Old Mill by a group of WPI students in 2018, which were viewed as successful (Wietzel, K., Lacoursiere, M., Russell, J., Rudd, E., personal communication, September 6, 2019).

The goal of our project was to design, build, and refine a set of interactive exhibits and associated interpretive materials for the Old Mill. To complete this goal, we fulfilled the following project objectives:

1. Determined best practices in the design and evaluation of interactive museum exhibits.
2. Evaluated the interactive exhibits developed for the Old Mill in 2018, and developed design criteria.
3. Designed, tested, and built new and revised interactives for the Old Mill.

As further stated in the methods section, objective three took up most of our time on Nantucket. Our main tasks on the island focused on the evaluation of the previous exhibits and construction of new and revised exhibits. The project team interviewed museum industry experts and conducted research on interactive exhibit design. Based on these interviews and background research, the team evaluated the previous exhibits used at the Old Mill. Based on our evaluation of the previous interactives, observations at the Old Mill, and feedback from NHA staff and volunteers, the team developed initial designs for new and repaired exhibits. Based on these

designs, the group built four functional physical prototypes and used iterative feedback from a school visit to improve these prototypes. One of these exhibits was also remade at a larger scale for its final iteration. The group also put together materials for a digital interactive exhibit. This included edited footage of the Old Mill and interviews of NHA staff, and a storyboard based on a rendering of the Old Mill. This process was repeated until our time on Nantucket ran out.

2. Background

This background section contains research on the different approaches museums take in presenting their information and how museums have changed over time to improve the visitor experience. In particular, our research focuses on interactive exhibits. This involved studies on the effectiveness of interactive exhibits compared with traditional, ‘static’ exhibits and the processes for designing and evaluating exhibits.

2.1 Museum Approaches and Interactive Exhibits

Museums and historic sites are constantly working to improve the visitor experience and increase visitation. To meet these goals, exhibit designers and evaluators have built a strong foundation of audience research that museums use to develop and refine exhibits and programming. Increasingly, museums are developing interactive exhibits because audience research reveals that they have the potential to engage visitors more effectively than traditional exhibit design. The NHA wants to further develop their interactive exhibits to enhance the visitor experience at the Old Mill.

2.1.1 Museum Visitation Trends

There are more than 35,000 museums across the US that span many disciplines, including art, science, and history (Institute of Museum and Library Services, 2019). The revenues generated by the museum industry are staggering, with more than \$50 billion of the US GDP being attributed to the museum sector in 2016 (Stein, 2018). For comparison, in 2015 the NFL, MLB, NBA, and NHL generated a combined \$31 billion (howmuch.net, 2016). More than 100 million people annually visit the 600 museums that are members of the Association of Science Technology Centers (ASTC) (ASTC, 2019). Visitorship for ASTC members has improved in recent years, with 67% of their members reporting an increase in visitors from 2016 to 2017 with the median number of annual visitors rising from 174,232 in 2017 to 204,040 in 2018 (ASTC, 2017-2018). Museums provide informal learning opportunities and employment for their communities. According to the American Alliance of Museums, museums supported more than 726,000 jobs in 2016 (Stein, 2018). Museums can also bring communities together by preserving a common heritage and working directly with community members when planning programs, exhibits, and expansions (Golding and Modest, 2013).

Museums strive to improve visitor experiences in order to compete with the growing range of alternative leisure options available to the public. For instance, the average US adult spends over eleven hours per day consuming some form of technological content (Nielsen Company, 2018). As a result, some museums have struggled to maintain attendance rates. Shown in Figure 1, the yearly attendance of the top historical museums in North America have not shown consistent improvement in recent years, displaying the difficulty in attracting new visitors. According to the National Awareness, Attitudes, and Usage Study by IMPACTS (Intelligent Models to Predict Actionable Solutions), as of 2017, the rate of replacement for museum visitors across 224 total museums was 0.948 new visitors on average for every visitor lost. For historic museums, this rate was slightly better, with an average of 0.951 new visitors for every visitor lost. The study also found that among adult visitors, “nearly four out of 10... don’t feel like art museums or history museums are ‘places for people like [them]’.” (Schneider, 2017).

Visitor Numbers at the Four Most Visited US History Museums 2013-2018

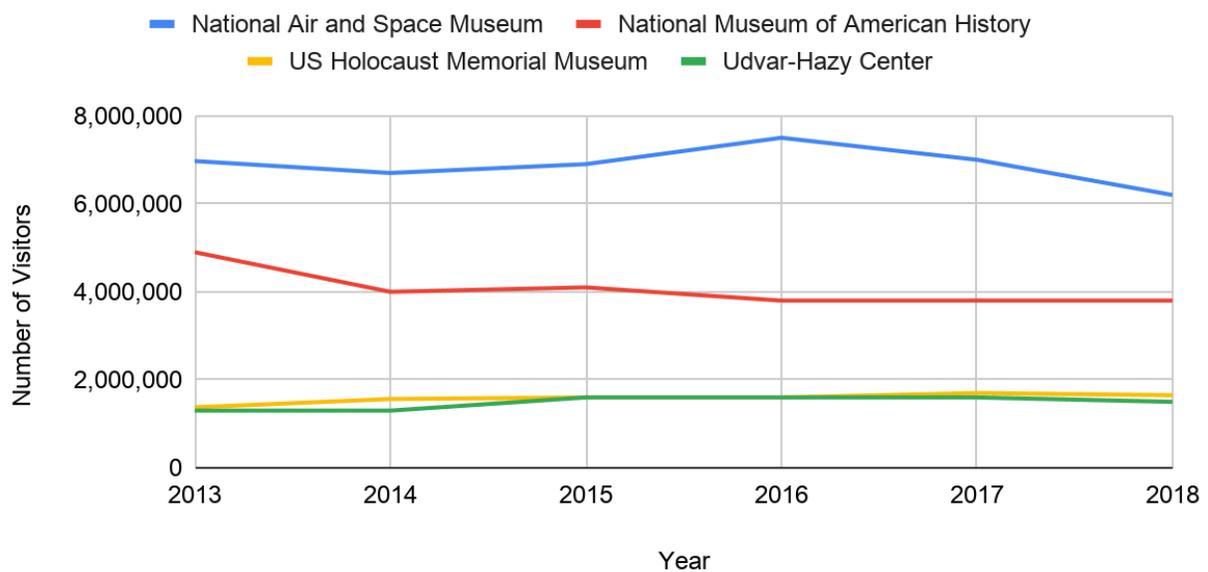


Figure 1: Recent Visitation Trends at Historical Museums (adapted from Themed Entertainment Association, (n.d.))

2.1.2 Evolving Approaches of Museums

The traditional goals of museums have been and remain education, preservation of collections, and research. While these basic goals remain, approaches to education through exhibits and programming have changed substantially in recent decades. Increasingly, museums have evolved from the use of static, didactic exhibits to more interactive exhibits that encourage constructivist exploration and discovery. Static exhibits generally consist of artifacts or artworks with common themes of time and place hung up on a wall or put in a glass case. Interpretive labels and plaques provide information about the origin and nature of each of the artifacts. An example of this would be in *The Value of Good Design* exhibit at the Museum of Modern Art in New York City, which was a collection of everyday objects, each labeled with a descriptive plaque (Museum of Modern Art, 2019). Artifacts are presented to the public as things to be preserved and observed, not directly interacted with, meaning there is minimal interaction between the display and the visitors (Black, 2005).

Living history museums take a different approach to fulfilling their goals. Living history museums have the same goals as traditional museums in education and research, but tend to depict the lives of ordinary people, rather than specific events, objects, or individuals (Anderson, 1982). In living history museums historical reenactors, often in period costumes, show how people went about their daily lives. These museums are usually located at historic sites and incorporate historic buildings and original or recreated artifacts that the reenactors interpret for the public (Murigi, 2018). An example of a living museum would be the Old Bethpage Village Restoration in Old Bethpage, New York. The museum contains 36 historic buildings, and the purpose is to demonstrate what daily life was like on 19th century Long Island (Old Bethpage Village, 2017). Living museum exhibits are less static and require a lot more visitor interaction than traditional exhibits, ranging from a verbal dialogue between the reenactors and visitors to various other hands on activities. While popular, living history museums have the same concerns as other museums in attracting and engaging visitors. For example, Colonial Williamsburg, one of the most popular living history museums in the world, has suffered declining admission revenue annually, from \$31 million in 2000 to less than \$20 million by 2011, having not risen above \$20 million since (Brauchle, 2017).

Historic tour operators face some of the same challenges of attracting and engaging visitors as do history museums. While not quite the same as museums, historic tours hope to

educate guests by guiding them through different historical locations and explaining their historical significance. Examples of walking tours include the Tri-Spy tours in Setauket New York (Three Village Historic Society, 2019) or the Downtown Walking Tour from the NHA in Nantucket (Nantucket Historical Association, n.d.).

For museums of all types, promotional events have been used to attract visitors as a supplement to exhibits. While not a recent development, the ability for museums to provide a varied experience can help motivate visitors to return for subsequent visits. There is little dispute among experts that these events drive community engagement and help attract visitors. However, even with active community participation, these events alone are rarely enough to deliver success (Igoe and Roosa, 2002; Golding and Modest, 2013).

2.1.3 Educational Engagement in the Museum

Over time, the goal of museum education has changed from passively informing visitors to actively engaging them. Exhibits have become more about visitors actively learning rather than presenting learning materials, as museums have pushed their visitors to be an integral part of the learning process. To do this, museums strive to “engage in learning as constructive dialogue rather than as a passive process of transmission” with “emphasis on learning from objects (rather than about objects) and on strategies for discovering information (rather than the information itself)” (Hawkey, p.2, 2004).

The general public now sees a museum as a “social space” (Black, p.304, 2018) one would visit with friends and family. The social aspect enabled by museums has come to be just as critical as the exhibits themselves (Griffin, 1998). Learning is more than just a one-time experience, and even individual learning moments have multiple outcomes. Learning “involves three overlapping contexts: the personal, the sociocultural, and the physical” (Falk and Dierking, p.10, 2000). Museums must consider each of these factors when designing galleries, exhibitions, and individual exhibits.

When interactive exhibits are made well, they naturally fit these goals by making learning a social experience that draws upon the background knowledge of visitors. They also allow for users of different learning styles to learn in a method that is more intuitive to them (Gardner, 2006). The change to interactive exhibits was prompted in part as schools and colleges

increasingly adopted active learning, and visitors increasingly sought high quality experiences beyond what static collections could deliver (Hooper-Greenhill, 2000; Black, 2005).

2.1.4 Interactive Exhibits

Interactive exhibits “are defined as those in which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input” (McLean, p.93, 1993). By allowing for audience participation, these exhibits communicate ideas to visitors in ways that are more engaging and effective than traditional, didactic approaches.

Interactive exhibits exist in two general categories; digital and physical. Of these, physical exhibits are much more varied in size and structure. The only limitation an exhibit has is that it needs to help visitors “discover and understand the phenomenon” (King, Ma, Armendariz, & Yu, p.95, 2018), whether that be with a small instrument that fits on a table or one that is so large it must be displayed outside. The most common digital exhibits are touch displays situated in walls or integrated in the large exhibit, but they also include “virtual reality systems, augmented reality systems, [and] haptics devices” (Zaharias, Michael, & Chrysanthou, p.375, 2013). The material covered in these exhibits usually take the form of some kind of simulation, be it a 3D rendering of a historical artifact or some more non-interactive viewing experience. Figures 2 and 3 show two examples of physical interactive exhibits and Figures 4 and 5 show two examples of digital interactive exhibits.



Figure 2: Smell Station at the Nantucket Whaling Museum



Figure 3: Drawers at the Nantucket Whaling Museum

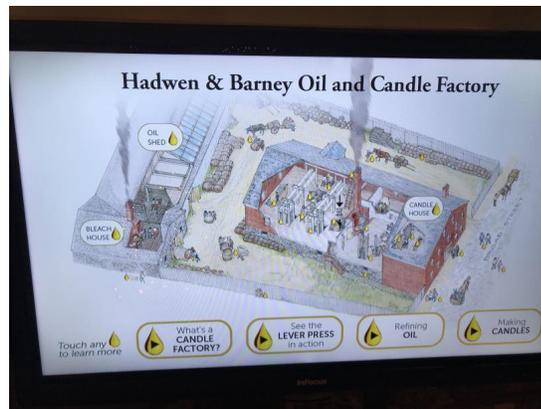


Figure 4: Hadwen & Barney Oil and Candle Factory Interface at the Nantucket Whaling Museum

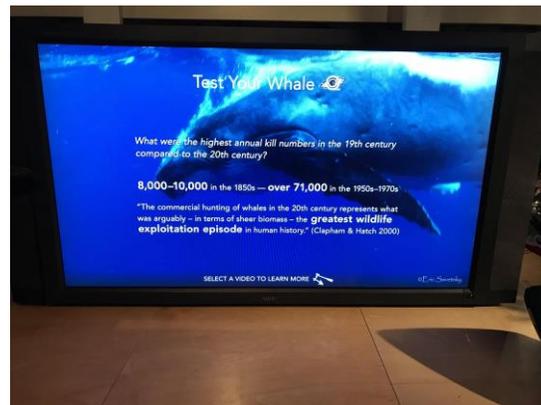


Figure 5: Test Your Whale Interface at the Nantucket Whaling Museum

One of the challenges in planning both physical and digital interactive exhibits is determining the target audience. Designers should acknowledge the differences in how adults and children learn, ensuring that the visitor experience is simultaneously entertaining and insightful for all who attend (Ringel, 2005). As established in section 2.1.2, museums are a social space, where groups of individuals of various age ranges and cultures gather to learn and have fun. As such, exhibits need to be designed with this dynamic in mind.

The standards for evaluating the quality of interactive exhibits expand upon the standards for evaluating traditional exhibits. Often what sets high quality interactive exhibits apart is in making learning an intuitive social activity. According to the Philadelphia-Camden Informal Science Education Collaborative (PISEC), interactive exhibits should meet seven design criteria. They should be, “multi-sided, multi-user, accessible, multi-outcome, multi-modal, readable, and relevant” (Borun and Dritsas, p.182, 1997). Similarly, a study of 1,800 students aged 10-12 found that exhibits that were the best at both retaining students and in facilitating discussion between them all had either a cooperative or competitive aspect. The exhibits that attracted the least interest from the students were unfamiliar, confusing, and unable to accommodate group participation (Shaby, Assaraf, and Tal, 2017).

Museum evaluators have examined the effectiveness of interactive exhibits in improving visitor retention and learning outcomes compared with traditional exhibits. Multiple studies have found that visitors, particularly children, rate their enjoyment of interactive exhibits more favorably than traditional exhibits, provided the exhibits are well executed (Allen and Gutwill, 2004; Shaby, Assaraf, and Tal, 2017; Zaharias, Michael, and Chrysanthou, 2013). Studies have also confirmed interactives engage users for longer than traditional exhibits (Hein, 2002; Hooper-Greenhill, 2000). Based on this evidence, many museums have sought to replace static exhibits with interactive ones, as time, budgets, and staffing allow. It is generally assumed that greater engagement (i.e. longer ‘dwell times’) improves learning outcomes, although some studies suggest that interactive exhibits do not significantly change learning outcomes for visitors (Zaharias et al., 2013). Other studies have found that visitor interaction with field experts can be just as useful at providing a learning experience as fully prototyped and tested exhibits, and this approach is a viable low budget alternative (King, Ma, Armendariz, Yu, 2018).

The relative effectiveness of digital and physical interactive exhibits is another consideration that museums must make. One study showed that visitors spent more time at

exhibits with digital guides than exhibits without them (Eghbal-Azar, Merkt, Bahnmueller, Schwan, 2016). Multiple studies have also found that digital displays and labelling for physical exhibits can increase time spent at exhibits, but it also can detract from the exhibit itself if the display is too involved (Roberts et al., 2018; Wang and Yoon, 2013).

While digital exhibits are popular with museums attempting to appear modern and relevant, the overuse of digital exhibits has been criticized. In particular, digital recreations of existing exhibits are seen as a waste of the technology's potential (Lang and Reeve, 2017). Other critics believe that digital interactives can inhibit and “overwhelm the slower, more complex forms of interaction” (Boon, p.4, 2000) that a visitor has with traditional exhibits.

2.1.5 Designing for Visitors

The process of designing exhibits can be broken down into the following three main parts; pre-exhibit planning/designing, exhibit planning/designing, and post-exhibit planning/designing. The pre-planning phase can be further broken down into a pair of sub-phases, the master plan phase and the feasibility study phase. The master plan phase is wide in scope, taking into account all major or minor needs that an exhibit must address. The feasibility study phase is meant to determine whether an exhibit will appeal to the target demographic while being feasible in terms of time and money (Bogle, 2013; Betsy Loring, founder of expLoring exhibits & engagement LLC, personal communication, September 18, 2019).

The exhibit planning/designing phase is broken down into a schematic/preliminary phase, an intermediate phase, and a final phase. The schematic/ preliminary phase answers the questions ‘what is the exhibit trying to accomplish?’ and ‘how are we going to get it done?’ Whatever is generated here needs to adhere to the master plan from the pre-planning phase. The intermediate phase is where the exhibit is studied conceptually and improved upon. This phase is an iterative process, with improvements happening slowly over time. The final phase is where all of the unsolved issues dug up in the intermediate phase are ironed out. This can include addressing accessibility issues, material constraints, and the overall visitor experience (Bogle, 2013).

The third and final phase is the post-exhibit planning phase, consisting of the construction/ installation and the post-opening sub-phases. The construction/installation phase is relatively simple, primarily consisting of a contractor delivering and assembling the exhibit. The post-opening phase starts after the exhibit debuts. In order to keep exhibits relevant, curators

must frequently update them. Exhibit maintenance is an ongoing process, with the goal of ensuring the exhibit remains in presentable condition for as long as possible (Bogle, 2013).

Exhibits are planned to meet their desired outcomes by fitting the aesthetic and practical concerns of the museum or historic site of which they are a part. Aesthetic concerns include aspects of the exhibit such as its ambience, and how well the exhibit fits in the context of its collection or location. Practical concerns include planning, construction, installation, storage, and maintenance. The physical attributes of the exhibit, such as lighting, shape, size, and materials, are decided in the design process. These attributes are critical in determining if the desired learning and engagement outcomes of the exhibit are met (Bogle, 2013).

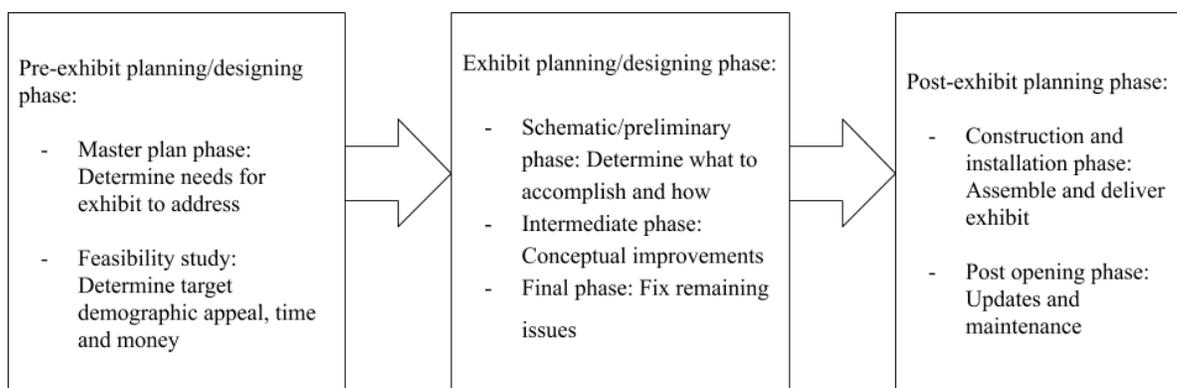


Figure 6: Exhibit Design Process

The methods by which exhibit designs are evaluated typically involve front-end, formative, and summative evaluation. Front-end evaluation takes place before the exhibit designs have been chosen and involves research into the themes and target audience for exhibits. This can be the longest part of a design process, as exhibit goals are narrowed down to specific objectives to complete (Screven, 1989; Downey, 2002). Formative evaluation takes place during the planning and designing phases of an exhibit's creation, and involves making improvements to the exhibit as it is being prototyped. This evaluation is performed by using external feedback to see which goals have been met, repeating for each successive prototype of the design. Prototypes are meant to be created and evaluated as quickly as possible, and the earliest prototypes should be made from simple materials, like paper (Betsy Loring, founder of expLoring exhibits & engagement LLC, personal communication, September 18th, 2019). The short duration of guest visitation naturally limits the effectiveness of formative evaluation for each prototype, meaning that prototypes must be developed in an iterative process (Hein, 2002). Summative evaluation is

performed after the design has been finalized and executed to construct the finished exhibit. Again, external feedback is used to determine whether the goals of the exhibit were met, and if not, whether it is possible to retrofit the current design to fulfill them (Screven, 1989).

Museums must carefully consider all aspects of their design, beyond just their exhibits. A museum's layout must carefully balance aesthetic and preservation concerns, while also ensuring that the museum can be easily maintained. Museum plans are typically divided into six departments: visitor services, retail, facilities, food, galleries, and security. This division is not strict, and each of these departments requires constant intercommunication to function (Lord, Lord, and Martin, 2012). Museum layout can also dramatically change visitors engagement with exhibits, with studies suggesting a balance between a restricted layout and an open layout is best for engagement. A constricted layout will minimize the opportunity for visitors to explore exhibits freely while an open and large layout motivates visitors to spend less time at each part of the area (Wineman and Peponis, 2009; Serrell, 1997).

2.2 The NHA

The NHA is the foremost historic society on Nantucket. Founded in 1894, the first curator, Susan Brock, described the NHA as “the custodian and conservator of the history of Nantucket...” (Nantucket Historical Association, 2019b). Since its founding, the NHA has acquired 25 historic sites and properties on Nantucket, including the Whaling Museum, the Oldest House, the Hadwen House, and the Old Mill (Figure 7). To effectively engage visitors and present its collections, the NHA uses a combination of the approaches as described in Section 2.1.2. For additional information about the NHA, see Appendix A.



Figure 7: Map of Significant NHA Properties
(Nantucket Historical Association, 2019d)

2.2.1 The Old Mill

Acquired just three years after the NHA's founding, the Old Mill is believed to be the oldest continuously operating windmill in the United States. Built in 1746, it stands over 50 feet tall and contains three levels, as shown in Figure 8. The Old Mill has seen three major renovations since the NHA acquired it, and still operates when the weather permits, grinding corn into cornmeal (Nantucket Historical Association, 2019f). It was designated a National Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers in 1992 (American Society of Mechanical Engineers, 1992). For additional historical background on the Old Mill, see Appendix A. For functional information about the Old Mill, see Appendix B.

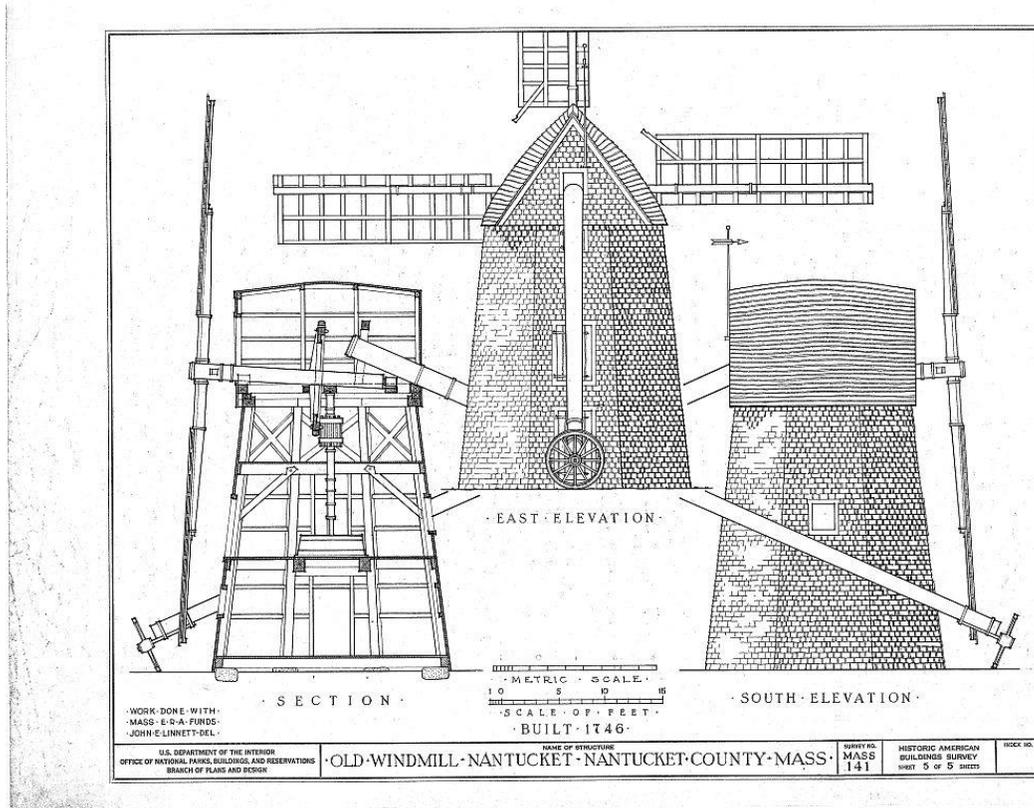


Figure 8: Survey Drawing of Old Mill, 1933
(Historic American Buildings Survey, 1933)

2.2.2 Recent NHA Efforts at the Old Mill

The NHA strongly emphasizes presenting the past in an engaging manner, indicated by one of their organizational objectives, to “Excel at Exhibition Presentation and Story Telling” (Nantucket Historical Association, 2019e). In order to increase visitorship, the NHA is striving to improve the visitor experience by exploring new ways to interpret exhibits and engage audiences. This approach has worked well, as the NHA has seen an increase in visitors in recent years, as seen in Table 1. A main focus of these new approaches has been the Old Mill (Wietzel, K., Lacoursiere, M., Russell, J., Rudd, E., personal communication, September 6, 2019).

Table 1: NHA Yearly Visitor Numbers (2015-2018) (Nantucket Historical Association, 2016, 2017a, 2018, and 2019a)

Year	2015	2016	2017	2018
Attendance	86,000	>90,000	100,000	103,000

As an example of recent efforts to improve the Old Mill site, a student team from WPI developed five interactive exhibits for the Old Mill in the fall of 2018 (Joseph, Phillips, Read, Thornton, 2018). These interactives were titled “How fast can you spin the grindstone?”, “Can you lift the Box O' Rocks?”, “How many sheets to the wind?”, “Race to the top!”, and “Who can make the windmill turn first?”. Images of each of these exhibits are located in Appendix C. All of these demonstrated some aspect or concept of how the mill operated. The Grindstone exhibit used a gearbox to demonstrate the effect different gear trains had on the speed of a grindstone. The Box O' Rocks exhibit used a pivoted wooden bar to demonstrate mechanical advantage using ropes of increasing distance from the pivot point. The Sheets to the Wind exhibit used a miniature model of the mill to demonstrate how large of a canvas sail to attach to the vanes. The Race exhibit used inclined planes and weights to demonstrate methods of getting grain into the mill. The Windmill turning used a set of user selected gears to demonstrate how gears can be used to accelerate the speed of the windmill. All but the last exhibit were constructed, tested, and evaluated by the WPI team (Joseph, et al., 2018). The NHA was very pleased with the performance of these exhibits since they were engaging and well designed, improving the general visitor experience (Wietzel, et al., personal communication, September 6, 2019). That being said, the NHA still noticed opportunities to improve the existing exhibits, even opting to add new ones.

3. Methods

The goal of our project was to design, build, and refine a set of interactive exhibits and associated interpretive materials for the Old Mill. To complete this goal, we fulfilled the following project objectives:

1. Determined best practices in the design and evaluation of interactive museum exhibits.
2. Evaluated the interactive exhibits developed for the Old Mill in 2018, and developed design criteria.
3. Designed, tested, and built new and revised interactives for the Old Mill.

Figure 9 illustrates the tasks associated with each objective that we discuss in more detail below. Figure 10 shows a timeline for the completion of these tasks. The third objective took most of our time on Nantucket, and it began as soon as the first two objectives were largely completed.

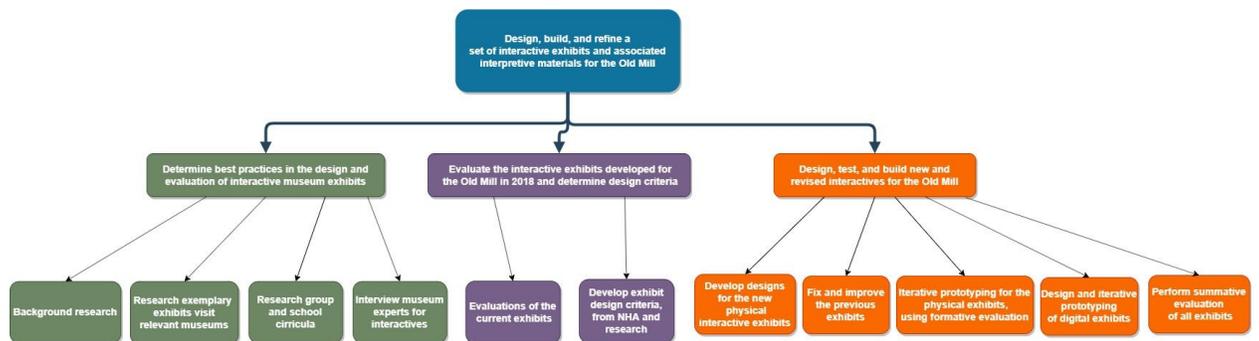


Figure 9: Goals and Objectives Flowchart

3.1 Determine Best Practices in the Design and Evaluation of Interactive Museum Exhibits

The first objective for the project was to determine how best to design and evaluate interactive museum exhibits. We conducted preliminary research on the standardized design and evaluation processes for interactive exhibits during and after prototyping. We gave additional consideration to digital interactive exhibits, what technologies are commonly used, and how other museum professionals develop them.

We continued our background research once we arrive on Nantucket. We reviewed internal NHA documents and resources on the success of the current exhibits, as well as more general visitor information about the NHA that was only available on the island. We conducted additional research on the incorporation of STEM curriculum concepts into our exhibits after initial consultations with NHA staff regarding their goals and expectations.

Before starting the design process, the project team observed other successful implementations of interactive exhibits. If we could not visit them in person, we reviewed the exhibits remotely by accessing online materials or conducting interviews. Some of the museums we looked at include the Exploratorium, the Nantucket Whaling Museum, the Nantucket Shipwreck & Lifesaving Museum, and the Ecotarium because our research indicated that they have exemplary interactive exhibits. Then, we determined commonalities between the most successful exhibits, generating a list of important factors to consider during design.

To gain further understanding of the exhibit design process, the project team conducted interviews with museum curators and exhibit designers. We developed a provisional set of interview questions, a version of which can be seen in Appendix D, but we tailored specific questions to match the interests and expertise of each interviewee. The team initially interviewed Betsy Loring, former lead exhibit designer at the Ecotarium, using this format. However, the rest of the interviews conducted were impromptu and less formal. The team asked about each individual's exhibit design process and for suggestions and advice on how to present Old Mill concepts for our exhibits. The team conducted informal interviews with Alice Promisel of the EcoTarium, Karl Weitzel of the NHA, and Mary and Al Novissimo of Novation Media. We conducted all interviews in-person. Phone interviews were considered as a backup method, but none were necessary. At least two members from the group conducted each interview, with one member leading the conversation and one serving as scribe. We began each interview with a

version of the preamble seen in Appendix D, where we solicited consent and explained the nature of our research. All interviewees had the opportunity to review any materials we used from the interview in our final report prior to publication.

3.2 Evaluate Current Interactive Exhibits for the Old Mill and Determine Design Criteria

We continued our front-end evaluation by observing the interactive exhibits previously displayed at the Old Mill. These exhibits were created for the project, “Exhibiting Simple Machines at the Old Mill”, completed by a team of WPI students (Joseph, et al., 2018). Our team met with key members of the NHA to discuss their impressions of the previous exhibits, what improvements they wanted to see, and what criteria they had for future designs. Additionally, the team requested access to visitor data collected by the NHA, especially regarding the current exhibits at the Old Mill. However, the NHA did not have visitor data to share.

We also discussed the current condition of the previous exhibits with the NHA and determined what needed to be improved upon. Specifically, the NHA found that the most important improvements necessary to the exhibits were in their durability, size, and uniformity. In the state we found them, the previous exhibits were too damaged to use and most of them were too bulky to transport easily. We consulted the NHA to see what the most viable options were for exhibit materials in terms of safety and cost efficiency.

We consulted the NHA and our research sources to develop design criteria that specifically target their key demographic of children aged 6-12 and their families. To aid the development of our criteria, we referred to our previous research regarding the STEM elements of the Massachusetts state curriculum. We made a set of design criteria for our physical exhibits based on our research, last year’s project, the NHA’s own criteria, and our own ideas.

3.3 Design, Test, and Build New and Revised Interactives for the Old Mill

Based on the group’s design criteria, feedback on the previous exhibits, and our own observations, the project team developed initial designs for the interactive exhibits. Our designs were all based around a theme of the different forces utilized at the Old Mill. The group obtained feedback from the NHA to ensure that the chosen designs were suitable before construction began. While our original intention was to make repairs to the previous exhibits, we determined

from our own observations and NHA feedback that rather than repairing their exhibits, we would reuse their best exhibit concepts. Since the main design improvements were based on durability, size, and uniformity, we decided to only rebuild their “Can you lift the Box O' Rocks?” exhibit and use gears similar to their “How fast can you spin the grindstone?” exhibit. The other exhibits were not workable ideas within our theming.

The project team used the NHA workshop to construct and repair exhibit prototypes. We assembled the initial prototypes using simple and cheap materials, mostly cardboard, in order to get feedback on our initial design concepts. Once the cardboard versions were reviewed by the NHA, we designed our subsequent prototypes in CAD. Using our 3D models, we constructed the prototypes with more durable materials, such as plywood. Formative evaluation for the exhibits followed a process of testing designs, soliciting feedback, redesigning, and retesting. We planned to use formative evaluation in this manner to quickly obtain feedback about our prototypes that we used for making the next iteration of prototypes. Once the first prototypes of our exhibits were assembled, the project team conducted formative evaluation with our first iteration of prototypes. To begin, we discussed appropriate locations for obtaining feedback with the NHA. These discussions focused on appropriate locations, days, and times for testing. We originally intended to use feedback from visitors to the NHA, but due to us being on Nantucket in the off season, we made observations and gained feedback from a 3rd grade class at Nantucket Intermediate School.

Before starting our lesson with the children, we briefly explained the nature of our research, and that we would be observing their interactions with the exhibits. We clearly stated that any observations we make will remain anonymous, to both the teachers and the children. During exhibit interactions, each exhibit was handled by one member of the project team, with other members remaining nearby to ensure safety and provide assistance if necessary.

Since our exhibit testing involved obtaining feedback from children, the project team directed the preamble to the accompanying teacher to obtain informed consent. After the preamble was discussed and consent was given, the children were allowed to interact with the exhibits. Once the children were done, the project team asked them survey questions, seen in Appendix E. No personally identifiable information about individual respondents were recorded with these questions. Also, before we asked the questions, we reviewed them with the NHA to revise them as necessary.

In addition to our physical exhibit prototypes, a digital exhibit was planned to provide instruction and interpretation for the Old Mill. The digital exhibit was designed to display simulated components of the Old Mill in operation, a rendering of the mill's interior when people cannot enter the mill, and a collection of interviews with people who have connections to the Old Mill. Each interviewee was asked questions about what the mill means to them. In some cases, other questions were asked about how the Old Mill works, the history of the Old Mill, and milling in general. To see a list of interviewees with the questions each was asked, see Appendix F. The digital exhibit was developed collaboratively with Novation Media, the designers for other digital exhibits used by the NHA. In the interests of time and consistency with the NHA's digital exhibits, we created a storyboard as a mockup for our interface, with edited footage from our interviews. We gave Novation Media this storyboard to allow them to construct the final interface that would be used at the exhibit site.

Once the physical exhibits were in a sufficiently final form to be made available to the public, the project team had planned to conduct the beginning of supplemental evaluation, using surveys to collect visitor observations. Since this survey could not be carried out during our time on Nantucket, we left the survey with the NHA in the event that they wanted to collect visitor evaluations for the finished exhibits. This survey can be seen in Appendix G.

Finally, we provided the NHA with recommendations for exhibit improvements and maintenance. These recommendations included potential design changes to our exhibits that went unfinished, additional exhibit designs that were not made, and materials used for each exhibit in case repairs are needed.

4. Project Outcomes

The intended outcome of this project was to provide the NHA with interactive exhibits that could be used to provide learning opportunities for the Old Mill. Starting with cardboard mockups, we progressed to 3D renderings and plywood prototypes of four physical interactive exhibits. We then solicited feedback on our prototypes from the NHA and five third grade classes at the Nantucket Intermediate School. We finalized the interactive exhibits based on feedback received and our own observations. Accordingly, we added minor functional improvements and stained the wood to better fit the Old Mill's aesthetics. We made a scaled up version of our Remade Box O' Rocks exhibit, as we felt that it would benefit the most from an increase in size based on the feedback that we received.

Along with our physical interactives, we put together materials for a digital interactive exhibit to help bring the Old Mill to life and provide accessibility. For our digital interactive, we conducted seven interviews of NHA staff with connections to the Old Mill. Using these interviews, footage of the Old Mill in action, and our 3D renderings of the Old Mill, we assembled a storyboard and edited clips to be made into the full exhibit. During the editing process, we obtained feedback on our clips and storyboard designs from the NHA and Novation Media. We sent the final versions of our storyboard and clips to Novation Media to be assembled into a full interactive consistent in appearance to digital exhibits at other NHA sites.

4.1 Physical Interactives

4.1.1 Brainstorming about Concepts and Design Criteria

Our exhibit development process started with brainstorming. We reviewed the Massachusetts school curriculums, various exhibits at the Whaling Museum, and our background research on best practices to identify ideas for potential exhibits. We also evaluated the interactive exhibits developed by the WPI team (Joseph et al., 2018) and found that while the concepts were good, most of the physical exhibits were in a state of disrepair. We decided to take some inspiration from their designs, but the NHA staff stressed that the exhibits were too large, insufficiently mobile, and not robust enough to merit repair. The NHA staff indicated that they wanted the new interactive exhibits to be more robust, portable, and engaging, among other qualities. The NHA staff emphasized that they expected us to derive our own conceptual designs, rather than just repair the previous exhibits. We decided to use elements of the Old Mill to

illustrate STEM concepts as the focus of our exhibits. We adopted and extended the design criteria from the previous WPI project, (Table 2), emphasizing portability, durability, and uniformity.

Table 2: Design Criteria from Our Physical Exhibits

Design Criteria for “Exhibiting Simple Machines at the Old Mill” (Joseph et al., 2018)	Our Design Criteria
Durable	Durable
Safe	Safe
Educational Value	Educational Value
Simple	Manageable Size
Creative	Portable
Innovative	Uniform
Accessible	Accessible

4.1.2 Cardboard Mockups

We began our physical prototyping by making cardboard mockups of our best ideas in order to quickly decide if they were worth building in full scale. Initially, we identified six potential interactives:

1. A brake to teach about friction
2. A gearbox to teach about inertia and translation of motion
3. A crank to turn on a light using a simple circuit with an LED and motor, to demonstrate the change from mechanical to electrical energy
4. A replacement to the Box O' Rocks exhibit from last year's project
5. A model mill that demonstrated how the tail pole could turn the top of the mill to face the wind
6. A winch to pull a cart up a ramp to demonstrate gravity

Based on NHA feedback, we decided that we would develop all these ideas as prototypes except for the last two exhibits. We and the NHA staff felt that making a working tail pole

exhibit would be unmanageable given our time and material constraints, and that the winch and cart exhibit had a concept that would require further development to be worth making. Figure 11 shows a cardboard mockup of our gearbox exhibit and Figures 12 and 13 show mockups of our tail pole and winch based exhibits.



Figure 11: Cardboard Mockup of Tail Pole Concept

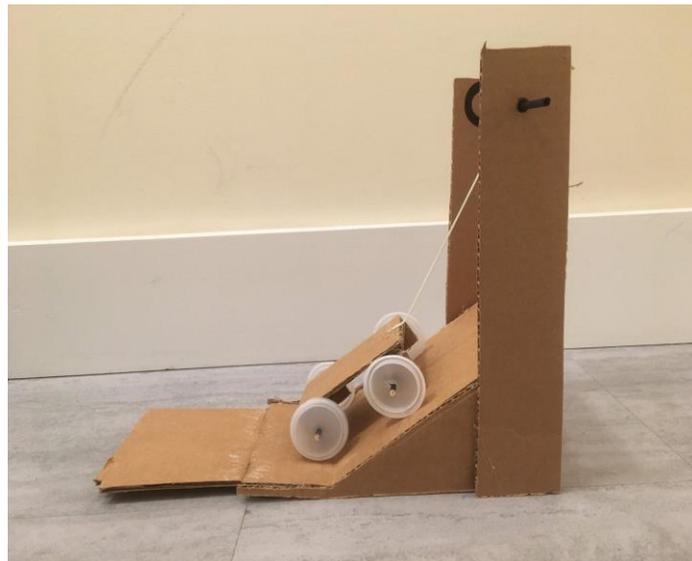


Figure 12: Cardboard Mockup of Winch Concept

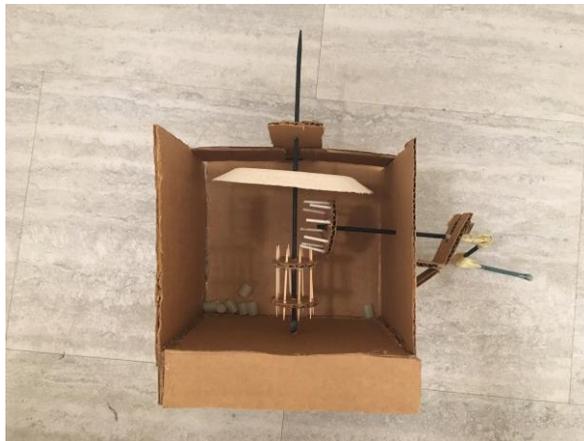


Figure 13: Cardboard Mockup of Gearbox Concept

4.1.3 Initial Prototypes

We developed the four remaining interactive concepts (numbers 1-4 above) as wooden prototypes at the intended scale of less than 2 feet on the x, y, and z axes. The main materials that we used for the exhibits was CDX plywood and 7/8 inch wooden dowels, as they were both cheap and available at the Gosnold workshop. To see a flowchart of some of the decisions we made in designing each exhibit, see Figure 14.

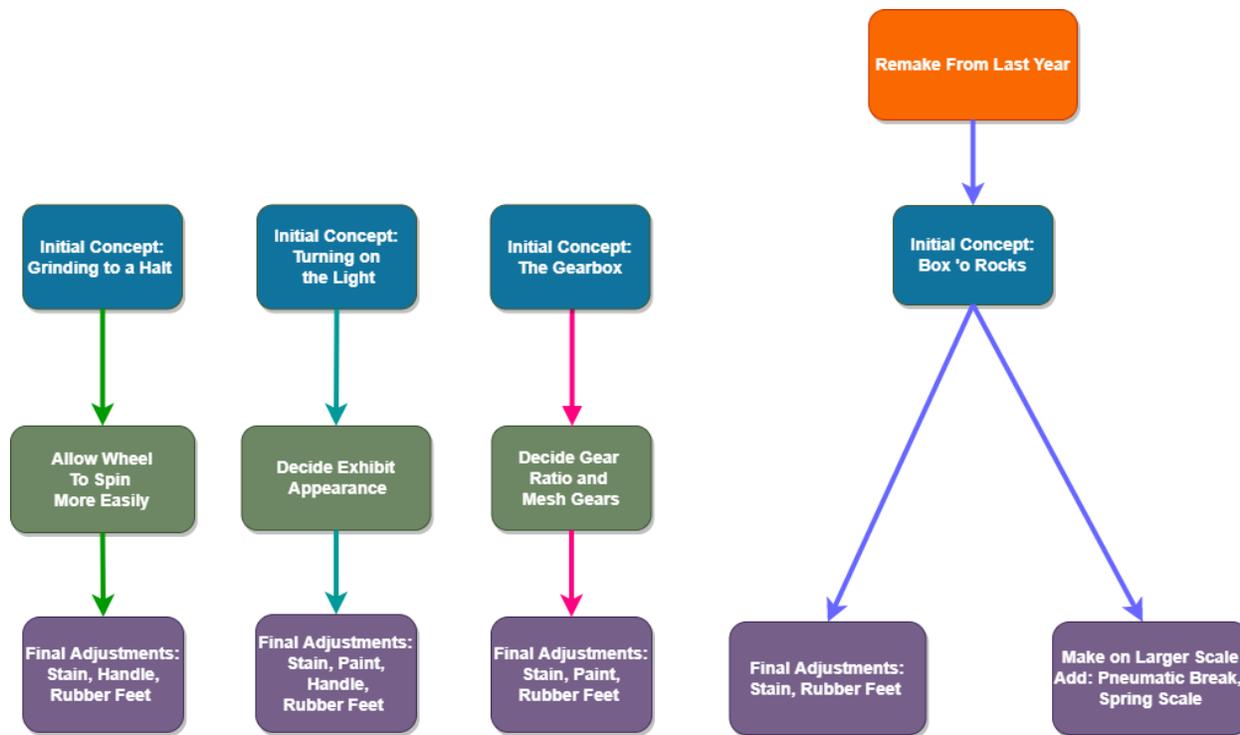


Figure 14: Decision Flowchart During Exhibit Fabrication

Grinding to a Halt

The first exhibit that we completed was Grinding to a Halt, which uses a brake and a spinning wheel to demonstrate friction and the static brake in the Old Mill (Figure 15). The biggest change we made from our cardboard mockup was the addition of a backboard to attach the brake and wheel together. We also included a handle on the brake to make braking easier. To reduce friction between the wheel and the backboard, we used a cut piece of PVC as a washer. Images of this exhibit's 3D model and plywood prototype can be seen in Figures 16 and 17.

The NHA said that Grinding to a Halt had the most room for improvement out of our prototypes, with the main criticism being that our original design was too simple. One well liked recommendation was to make interchangeable wheels with different materials on each wheel. This would allow for users to experiment with the amount of force needed to brake each wheel.



Figure 15: Static Brake in the Old Mill

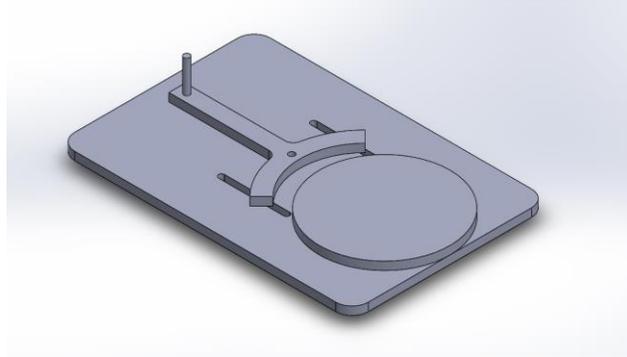


Figure 16: Grinding to a Halt 3D Model

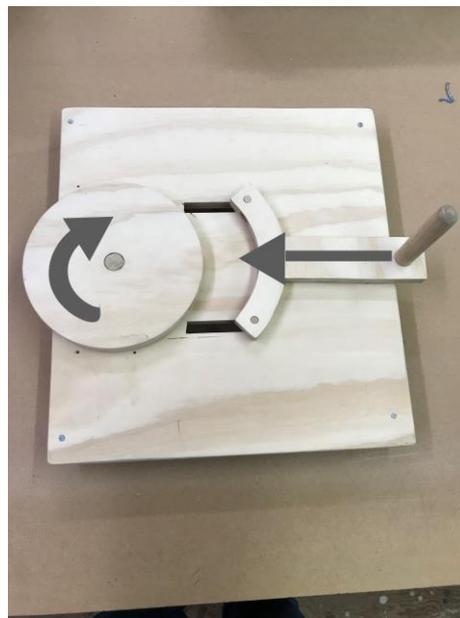


Figure 17: Grinding to a Halt Plywood Prototype

The Box O' Rocks

The second exhibit we made was a remake of the previous project team's Box O' Rocks exhibit. As with the previous Box O' Rocks, the inspiration for this exhibit was the counterweight for the static brake in the Old Mill. The main lever arm was built with three pegs on each side of a fulcrum, using S-hooks to secure a weight and a rope to the pegs. Users can adjust the distance of the weight and rope to the fulcrum, making the weight more or less difficult to lift. These changes from last year's exhibit were made to provide additional exploration and experimentation. Images of the exhibit's initial CAD design and plywood prototype can be seen in Figures 18 and 19.

The idea of a Box O' Rocks remake was well liked by the NHA staff, as the Box O' Rocks was seen as the most successful exhibit that was made last year. The main design improvement suggested by the NHA for this exhibit iteration was to add cushioning if users let the lever fall. This cushioning would be used to slow down the lever's descent after users let it go. Other suggestions included a different fastener than S-hooks for ease of use, interchangeable weights to encourage exploration and experimentation, and a spring scale to demonstrate to users the force needed to pull up the weight. After completing the first iteration of the lever prototype, the NHA staff further suggested that the exhibit would be more entertaining at a large scale.

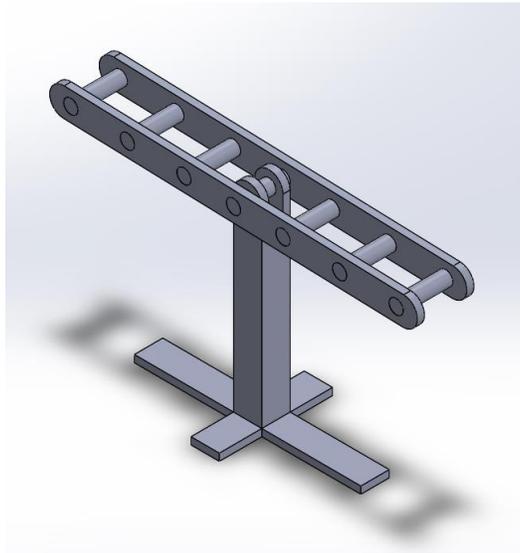


Figure 18: Remade Box O' Rocks 3D Model

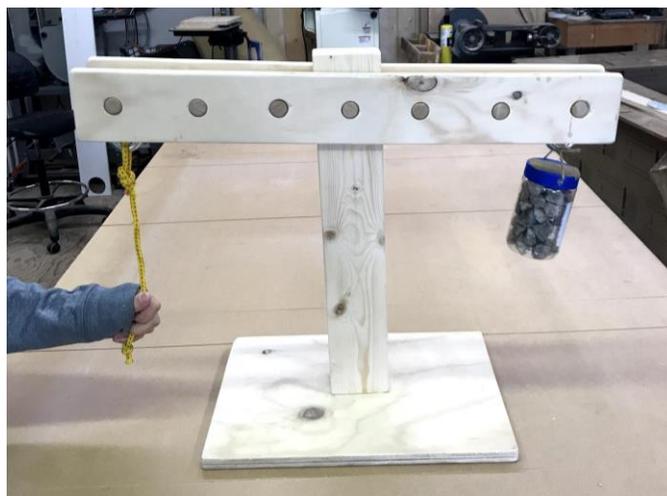


Figure 19: Remade Box O' Rocks Prototype, with Adjustable Weight and Rope

The Gearbox

The third exhibit that we created was the Gearbox. This exhibit demonstrates the concepts of inertia and translation of motion using a gear assembly. Our exhibit was modelled after the Old Mill's crown and cage gears, with a wooden "grindstone" attached above the cage gear. Users can rotate the gear assembly by using a crank. While the gears are spinning, users can drop corn onto the grindstone to see how the corn spins off. This exhibit was built with plexiglass siding to permit visibility and to prevent the corn from making a mess. We began the construction of this exhibit by making a 3D model, choosing a convenient gear ratio of 2:1 to ensure that the gears meshed properly. See Figures 20 and 21 for the model and prototype gearbox.

The NHA liked the Gearbox prototype, as they felt it captured the sound and appearance of the Old Mill. The main NHA suggestion for the Gearbox was to add a funnel that would direct the corn to a hole in the box for easy collection. The NHA also suggested painting the exhibit's grindstone to more closely resemble stone.

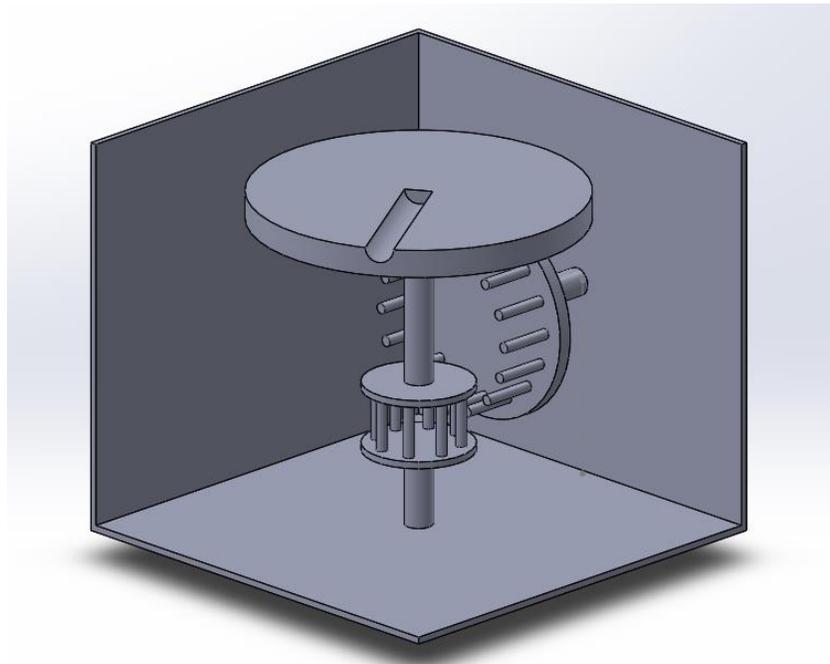


Figure 20: Gearbox 3D Model



Figure 21: Gearbox Plywood Prototype

Turning on the Light

The final exhibit that we completed was our light-based exhibit, Turning on the Light. By turning a crank, users can generate enough power to turn on an LED. This demonstrates how a turbine converts wind into electricity. Initially we wanted the exhibit to look like the Old Mill, with the user turning the vanes, as seen in Figure 22. Due to safety concerns and the potential fragility of the vanes, we designed the exhibit with a simple crank instead. When we designed this prototype exhibit, we kept the same circuit from our cardboard mockup, but with a gear train attached to the handle so that the light would be easier to turn on. We made a small light stand that the LED was wired through to hide the circuit. The light stand was housed inside of a small display, with a plexiglass wall to let users see inside. See Figures 22 and 23 for this exhibit's 3D model and plywood prototype.

The concept of Turning on the Light was well received by the NHA. However, the NHA felt that the exhibit would be more enjoyable if the light was easier to see and stayed on for longer.

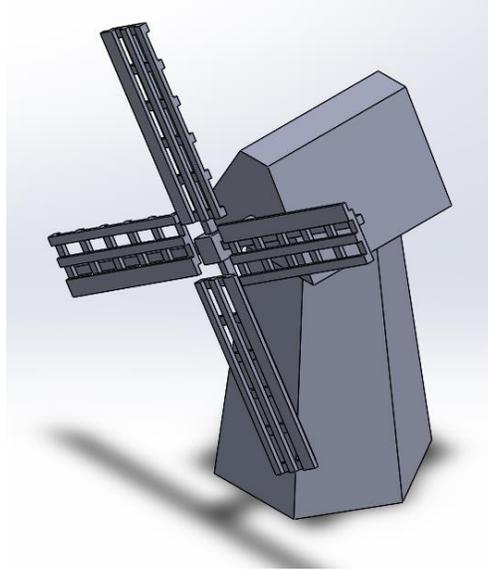


Figure 22: Turning on the Light 3D Model

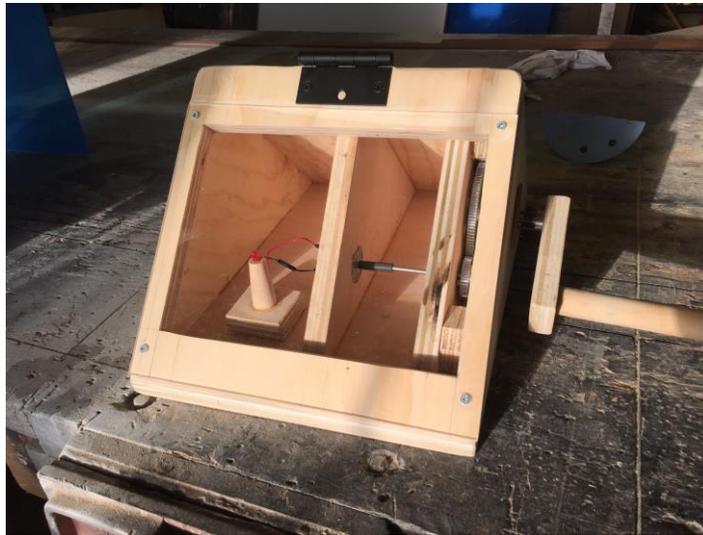


Figure 23: Turning on the Light Plywood Prototype

4.1.4 Prototype Feedback

Since few families with children visit the museum in the off season, we were not able to solicit feedback about the prototypes on the museum floor. Instead, we decided to get feedback from five classes of third graders from the Nantucket Intermediate School. We began by coordinating a visit with Kathleen Mooney, one of the third grade teachers. Once we planned this visit to happen on 11/20/19, we prepared our exhibits and planned what we were going to discuss

with the students. When we arrived at the school, we divided each class into four groups, with each of us individually explaining one of the exhibits to each group, as seen in Figure 24. After our explanations, we let the students play with the exhibits on their own with supervision. While they were playing with the exhibits, we asked the students simple questions about the exhibits to obtain their feedback.



Figure 24: Bringing the Exhibits to Nantucket Intermediate School

From the students, we received many of the same suggestions that we received from the NHA. A common suggestion from the exhibits was to add something on the bottom of each exhibit to prevent the exhibits from sliding while in use. This would be especially helpful for our exhibits since they were designed for portability, and could be brought to other locations than just a classroom.

Grinding to a Halt communicated the concept of friction well. The most common suggestion for improving this exhibit was to add a handle to the wheel so that it is easier to spin. A few students wanted the wheel wobble less as it rotated, and one voiced a concern that people could get their fingers stuck under the wheel. Also, we found that the style of the exhibit could be improved to better resemble the mill, since many students mistook the wheel, which was supposed to be analogous to the Old Mill's the crown gear, for the grindstone. In terms of making the exhibit more fun, there were a few suggestions to make interchangeable wheels, as the NHA staff had suggested.

For the Box O' Rocks replacement, the students most enjoyed lifting the weight in the heaviest configuration. Many of the students wanted the exhibit to be scaled up, with the most

common requests for the exhibit to make it bigger, heavier, and with more weights to add or remove. An important observation we made was that this exhibit had potential safety concerns since the S-hooks kept coming loose. Otherwise, the exhibit was well liked, and the students could easily understand the exhibit's concepts.

There was no surprise that the Gearbox was one of the most popular of our prototypes. While we had noticed that the gearbox was loud before bringing the exhibits to the school, we had not found it to be a problem until it was being demonstrated during explanations. The students enjoyed pouring corn onto the grindstone, but the amount of corn that we brought to the classroom was not enough to meet demand.

Turning on the Light was also a popular exhibit. For this exhibit, we found that the crank's handle would be improved if it could spin freely, since having a fixed handle made it difficult to turn the crank fast enough to light up the LED. The students also put enough effort into turning the crank that the metal shaft secured to the crank was bent. The students also recommended we make the light stand for the LED look more like a lighthouse. They also suggested replacing the light stand with a light bulb or a larger and brighter light.

4.1.5 Finalizing the Prototypes

For recommendations about packaging the final exhibits, we and the NHA were in agreement that a common wood stain was important for uniformity and aesthetics. We also considered adding faux wear and tear to the exhibits so they would better fit the mill's aesthetic. We also gave each of the exhibits rubber feet to prevent the exhibits from sliding. For Grinding to a Halt, we added a handle to the wheel to make it easier to rotate (Figure 25).



Figure 25: Final Version of Grinding to a Halt Exhibit

For the Box O' Rocks remake, we secured the lever arm so that it would be more difficult to take apart. For the Gearbox, we painted the grindstone to make it look more like granite (Figures 26 and 27).



Figure 26: Final Version of the Remade Box O' Rocks Exhibit



Figure 27: Final Version of the Gearbox Exhibit

We painted Turning on the Light's light stand to resemble the Great Point Lighthouse on Nantucket (Figure 28).



Figure 28: Turning on the Light's Repainted Lighthouse

We also added a free spinning handle to the crank that made it easier to grip while rotating (Figures 29 and 30).



Figure 29: Final Version of Turning on the Light Exhibit



Figure 30: Free-Spinning Handle for Turning on the Light

Since the NHA and third grade students were both in agreement that the Box O' Rocks exhibit would benefit the most from being scaled up, we made a larger version of the Box O' Rocks exhibit. We made the exhibit similar in size to last year's Box O' Rocks, but added some improvements. We included a pneumatic brake (Figure 31) to slow the fall of the lever so that it would be subjected to less stress. We also added a spring scale (Figure 32) where users would pull on the rope to quantify the force they would need to exert to lift the box of rocks. Finally, we made the center post thicker than last year's exhibit to strengthen it. See Figure 33 for the Remade Box O' Rocks exhibit.



Figure 31: Spring Scale on Box O' Rocks



Figure 32: Pneumatic Break on Box O' Rocks



Figure 33: The Remade Box O' Rocks

4.2 Digital Interactive

In addition to our physical interactives, the NHA was keen on the idea of using a digital interactive exhibit to teach about the Old Mill and its history. The NHA also wanted to use the digital interactive to provide accessibility to the Old Mill. As a historic property, the Old Mill cannot be renovated to meet ADA standards, restricting or preventing access for many visitors. Additionally the mill is not always open and running when other properties and the Whaling Museum are open. A digital interactive would show the mill in motion to those who otherwise would not be able to see it.

Our original goal in the design of our digital interactive was to make an exhibit that was similar to other digital NHA exhibits. However, we and the NHA agreed that we would not have the time necessary to make the exhibit with the same quality and appearance as other digital exhibits at NHA properties. So, instead of making the digital exhibit ourselves, we recorded the footage necessary for the exhibit and made a storyboard of how we envisioned it would look. Once we completed our version of the storyboard and our clips, we sent these materials off to Novation Media to be assembled into the final exhibit.

A major inspiration for our exhibit was the candle press interactive at the Whaling Museum (Fig. 34). The starting screen for that exhibit displays a layout of the old candle factory with many small oil drop icons over important places. When a user touches one of the icons, information relevant to the icon's location appears.

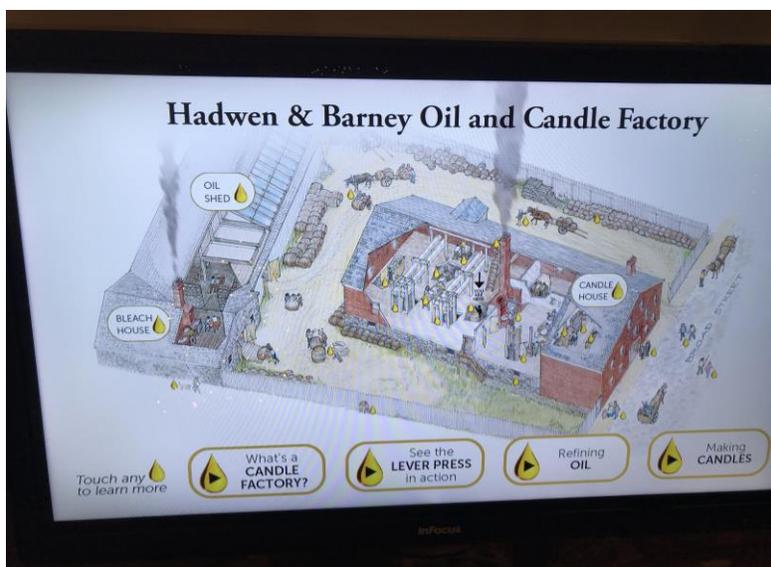


Figure 34: Candle Factory Interactive at Whaling Museum

Our interactive applies the same general format as the candle press exhibit. The starting screen for our exhibit shows a 3D model of the Old Mill in motion where users can touch icons placed over important parts of the mill (Fig. 35). Rather than showing informational text, the display would show a one-to-two minute video clip of an NHA interpreter describing that part of the mill and telling stories associated with it. These videos are made up of clips of our 3D rendering in motion, footage of the Old Mill in operation, and interviews we conducted.



Figure 35: A Mockup of the Digital Interactive Home Screen

The interviews that we conducted were meant to add a personal element to the exhibit, providing narration and information for our clips. All of the interviewees were picked based on connections to the Old Mill, and were interviewed at separate NHA properties. A table of the interviewees, their position at the NHA, and a general overview of what we learned during their interviews can be seen below in Table 3.

Table 3: Interviewees, Their Titles, Why We Interviewed Them, and What We Learned

Name	Title/Position	What We Learned
Elizabeth Gilbert	NHA Historic Sites Interpreter	John Gilbert's work at the mill.
Joe Bedell	NHA Miller, Maintenance and Fabrication	History of the mill and information on Dick Swain
Tom Miner	NHA Miller	Full tour of mill
Manny Sylvia	NHA Miller and Maintenance	Stories about working at the Old Mill
Karl Wietzel	NHA Historic Sites Manager and Miller	General Milling History
Susan J. Berman	Singer / Songwriter Former NHA Historic Sites Interpreter	The process for writing the song "This Old Mill"
Joanne Polster	Former NHA Historic Sites Interpreter	Interpreter's Perspective on the Old Mill

5. Conclusions and Recommendations

From our visit with the third graders, we conclude that our interactive exhibits are engaging to a younger audience. We also conclude that the exhibits appear to be effective at conveying the STEM concepts of friction, forces, levers, translation of motion, inertia, and energy conversion.

We conclude that the interactives will enable the NHA to extend the learning opportunities presented by the Old Mill. The interactives can be used at the Old Mill to engage visitors on site, even if they cannot ascend the stairs or enter the mill. When the Old Mill is closed, the interactives can be taken to the Whaling Museum. Finally, the portability of the interactives means they can be used in educational programming at the museum or directly in schools. This would accomplish the NHA's intended goals of providing learning opportunities and improving intellectual access to the aspects of the Old Mill for as many people as possible.

For each of our physical exhibits, we created a set of recommendations for improvements that we did not have time to make, but the NHA could implement in the future. One overall recommendation is that the NHA continue to solicit feedback from visitors, school groups, volunteers, and staff about additional modification that might enhance the operation and durability of the interactives and their effectiveness as learning tools.

For **Grinding to a Halt**, we recommend that the NHA add interchangeable wheels of different sizes and with different materials on their exteriors. By spinning the different wheels and seeing how quickly the wheels slow down, the user can explore what affects friction. For example, a wheel lined with rubber will be easier to brake with than a wheel lined with steel, which shows there is more friction when wood contacts rubber than when it contacts steel. See Figures 36 and 37 for examples of potential wheels. We also recommend that the NHA change the appearance of the wheel to make it look more like the Old Mill's crown gear, since that was an area of confusion for the third graders. This could be accomplished by painting a cogged wheel or by gluing a thin plywood gear to the surface of the disc. We also recommend reducing the amount the wheel wobbles when spun by using a fixed axle with only the wheel rotating.



Figure 36: A Rubber Band around a Wooden Disc



Figure 37: A Steel Band around a Wooden Disc

For our smaller **Box O' Rocks** exhibit, we recommend that the NHA add a pneumatic brake to prevent the lever from falling too quickly. Adding a pneumatic brake to this exhibit would prevent the weight from falling too quickly by slowing its descent, such as the pneumatic door closer which was added to the scaled-up Box O' Rocks. We also recommend that the NHA use carabiners as a better way to attach the weight and rope to each peg, since S-hooks can detach during use.

For the **Gearbox**, we recommend that the NHA adds a funnel for collecting corn dropped off the grindstone. We have two potential ideas for how the funnel could be added to the exhibit. The first way would be to angle the floor of the exhibit so the corn collects in a bin. The second way would be to install an angled plexiglass divider between the grindstone and the gears that catches the corn and funnels it off. A bucket or other collection device would be placed to collect all of the corn from the funnel. This would remove the need for NHA staff to clean out the

exhibit after it has been used and would minimize the amount of corn needed in demonstrations since the corn is collected and fed directly back into the exhibit.

For **Turning on the Light**, we recommend that the light be made easier to see. To accomplish this, we recommend adding more gears to the gear train, making it easier to turn on the light. Below is a figure of a gear train that would allow the light to turn on with a slower crank rotation (Figure 38). While we recommend using a gear train with four gears as a first suggestion, the NHA could make the gear train longer if necessary. These modifications could be done without the need of a larger exhibit footprint, but would require the current exhibit to be disassembled and rearranged internally.

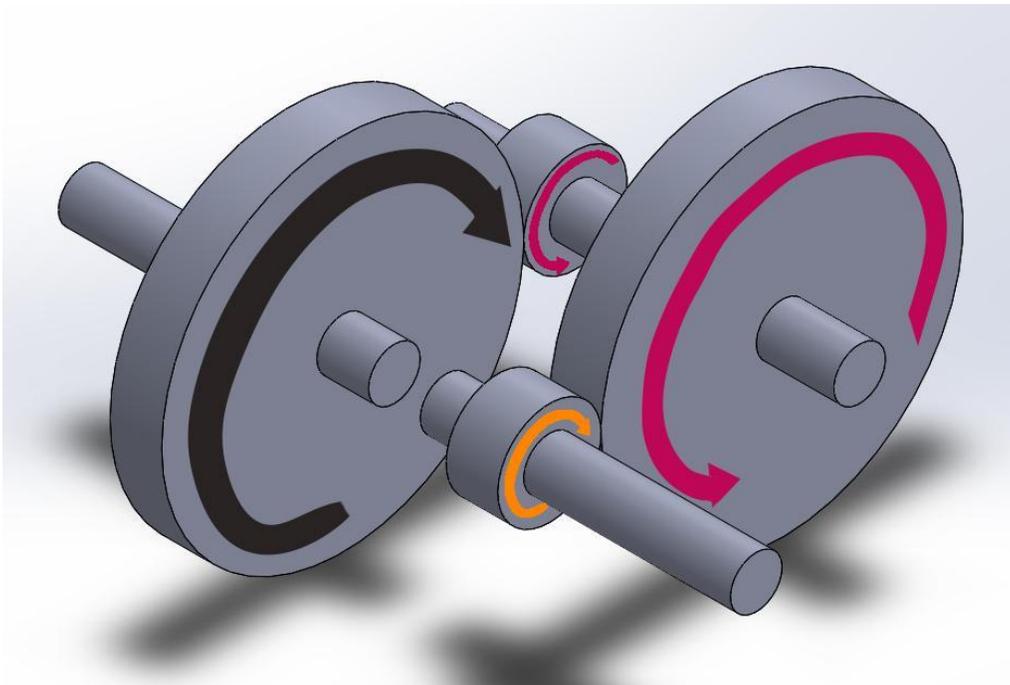


Figure 38: An Improved Gear Train for Turning on the Light

For maintenance, we believe that the NHA's maintenance team is highly capable of repairing these exhibits and keeping them in working order. We still recommend that the exhibits are stored inside to prevent unnecessary damage.

We recommend that, as planned, Novation Media use our edited clips and storyboard to create a digital interactive exhibit. Once completed, we recommend that this exhibit should be available at the Old Mill, in the Whaling Museum, and on the NHA's website. We think that showing the exhibit on site would be the best way to provide accessibility to visitors who physically cannot enter the mill. Additionally, showing the exhibit on the NHA's website would help reach the largest audience possible. We also recommend that the NHA continue to conduct interviews of NHA staff that have relevance to their historic properties. We believe that this is especially important for NHA staff members that are approaching retirement or have already retired, since we believe that preserving their stories is critically important.

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Appendices

Appendix A: Description of the NHA

The Nantucket Historical Association (NHA) is a nonprofit organization devoted to the conservation of Nantucket's historical buildings and collections. Their mission is to “preserve and interpret the history of Nantucket through its programs, collections, and properties, in order to promote the island's significance and foster an appreciation of it among all audiences” (Nantucket Historical Association, 2019e). The NHA was established in 1894 with the purchase of the Quaker Meeting House. Three years later, the NHA acquired the Old Mill, which is the oldest American grist windmill still in continuous operation (Figure 1).



Figure 1: The Old Mill
(Nantucket Historical Association, 2019f)

The NHA has also acquired over 25 historical properties and sites on Nantucket (Figure 2). Chief among these locations is the Whaling Museum, which has been cited as the catalyst that “suddenly transformed [The NHA] from a grass-roots collective to a modern nonprofit organization” (Bruggeman, p.188, 2015).



Figure 2: Map of Significant NHA Properties
(Nantucket Historical Association, 2019d)

The Whaling Museum opened in 1930 and is the NHA's flagship attraction with the highest annual attendance of all of their sites, at about 90,000 visitors per year (Nantucket Historical Association, 2019b). Renovated and expanded in 2005, it houses artifacts of the whaling industry in a historic whale oil refinery including scrimshaw, whaling harpoons, and even an entire whale skeleton (Figure 3) (Nantucket Historical Association, 2019b). The NHA also hosts special exhibitions that feature traveling exhibits along with related items from the NHA collection. For example, a selection of the art of Seward Johnson is on display until December 2019 in collaboration with the Artist's Association of Nantucket (Nantucket Historical Association, 2019c).



Figure 3: Whale Hunt Gallery in the Whaling Museum
(Nantucket Historical Association, 2019g)

The NHA employs over a hundred people, including administrative, educational, and curatorial staff, and their board of trustees comprises 31 members. (Nantucket Historical Association, 2019a). The current executive director of the NHA is James Russell, Mary Lacoursiere is the Chair of Education, and Edwin Rudd is the director of Facilities. As of the end of the 2018 fiscal year, the NHA’s assets totaled almost \$40 million. There are several other museums on Nantucket, but the NHA is by far the most visited. The Nantucket Maria Mitchell Association, a nonprofit organization on Nantucket that focuses on science education, is the second largest museum with net assets totaling a little more than \$10 million as of 2016 (Maria Mitchell Association).

The NHA’s Strategic Plan lists five organizational objectives. These objectives include increasing community investment, improving the accessibility and usage of their historic properties, and strengthening the organization (Nantucket Historical Association, 2019e). The most relevant objective to our project, though, is to “Excel at Exhibition Presentation and Storytelling” (Nantucket Historical Association, 2019e). The NHA wants to generate “informed encounters with the past” to help teach visitors what life on the island used to be like (Nantucket Historical Association, 2019e).

Recognizing the need to continually improve their visitor experience, primarily through maintaining its collections and community outreach, the NHA has seen an increase in visitor attendance over the last several years (Table 1). In recent years, several museums have

Table 1: NHA Yearly Visitor Numbers (2015-2018) (Nantucket Historical Association, 2016; 2017; 2018; and 2019a)

Year	2015	2016	2017	2018
Attendance	86,000	>90,000	100,000	103,000

tried introducing interactive exhibits to keep visitors' attention for longer and to improve the visitor experience overall (Zaharias, Michael, and Chrysanthou, 2013). Interactive exhibits are defined as "those in which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input" (McLean, p.93, 1993). Studies have shown these exhibits are significantly more engaging than traditional exhibits, making them ideal for the NHA to implement (Zaharias, Michael, and Chrysanthou, 2013).

Our group's project is intended to assess and potentially refurbish or replace the Old Mill's interactive educational exhibits that were developed by a WPI student team in 2018. Built in 1746, the Old Mill has seen three major renovations since the NHA acquired it, and has in the past been used for grinding corn. The Old Mill is a focus of recent improvement efforts from the NHA. The exhibits currently shown at the Old Mill demonstrate the mechanics of the mill in operation. The NHA hopes that improving the quality of the interactive exhibits will enhance the visitor experience and ultimately encourage increased visitation.

Appendix B: Additional Old Mill Information

The Old Mill is a wind powered grist mill, primarily used grind corn into cornmeal. The mill has four sails, and each sail is covered with two to four sail cloths depending upon weather conditions. The rotation of the sails spins the windshaft, a long wooden pole attached to various gear trains within the mill. One of the most important devices powered by the windshaft is the top mill stone, which accomplishes the actual grinding. Once the corn has been ground, the cornmeal falls into a sifter, which separates out the larger pieces. The finished cornmeal is then processed into individual packages. On the exterior of the mill is the tail pole, which is used to rotate the head of the mill so the sails are facing the wind. The mill's optimal operational speed is when the wind is blowing at 10-15 knots and the sails pass by the window every two to three seconds (Nantucket Historical Association, 2017b).

Appendix C: The 2018 Project Team's Interactive Exhibits at The Old Mill



Figure 1: How fast can you spin the grindstone?
(Joseph, et al., 2018)



Figure 2: Can you lift the Box O' Rocks?
(Joseph, et al., 2018)



Figure 3: How many sheets to the wind?
(Joseph, et al., 2018)



Figure 4: Race to the top!
(Joseph, et al., 2018)



Figure 5: Who can make the windmill turn first?
(Joseph, et al., 2018)

Appendix D: Museum and Exhibit Expert Interview Preamble and Questions:

We are a group of students from Worcester Polytechnic Institute (WPI) conducting a research project in collaboration with the Nantucket Historical Association to design and build interactive exhibits for the Old Mill. We would be delighted if you would take 20 minutes to answer some questions about interactive exhibits, including design, instructional materials, digital interfaces, and particularly exhibits that have done exceptionally well for your museum/institution. Your participation in this interview is completely voluntary and you may stop at any time, or skip any questions that you would not like to answer. We shall be taking notes during our conversation and may wish to quote you in our final report.

Do you mind if we quote you, or would you prefer we completely anonymize your responses? If we can quote you, would you be willing to let us use your name? We will not use any personally identifiable information about you without your consent. We will give you an opportunity to review any quotations we use prior to publication. We will also be happy to provide you with a copy of our report when it is completed.

Thank you for your supporting this research. Do you have any questions before we begin? If you have any concerns or questions after the interview, you can contact us at gr-ACK19-NHA@wpi.edu or our faculty advisor, Dominic Golding, at golding@wpi.edu.

Interview Questions and Loose Script:

- In your own words, please describe to us what you do in your job? While we know that you are a _(job title)_ who worked at/ is working at _(institutional name)_, we would like to hear what that entails.
- Which exhibits would you say are among your institution's best? Why are these exhibits so successful? Were there any exhibits that were unsuccessful that you would be willing to share with us?
- Would you say that there is anything in designing exhibits that we might not expect? What would you say is the hardest part of the design process? We know prototyping likely takes the most time.

- Do you have any advice for attracting visitors to test your exhibit prototypes?
- Since we are working on a short timeframe, (about 7 weeks), what can we potentially leave with the NHA if we do not have much time to do it ourselves?
- Did you/do you handle school groups differently than other types of visitors such as family groups? What about scout groups and boys/girls' clubs?
- Do you have any museums/exhibits that you would personally recommend to us, at either your institution, or other places?

Appendix E: School Interpretive Questions

Preamble:

Hello! Our names are Avery, Kathryn, Peter, and Ryan and we are college students at WPI. We are working the Nantucket Historical Association to create new museum exhibits for the Old Mill. Part of our project involves asking people to test and give us feedback on our exhibits. We will not write down your names, but we will be taking notes. Once you are done at our station, we will ask you questions about the exhibits.

Visitor information:

Group Number # _____

Group Size: ____

Number of Girls: ____

Number of Boys: ____

Prototype Versions:

Exhibit Name: _____

The instructor will make notes here if any children were injured by the exhibit:

The instructor will make notes here about anything that broke, or can be improved:

Other Instructor Notes:

General Questions:

What did you learn?

Did you have fun?

Was the (add name of exhibit) easy to use?

How did the exhibit look?

Exhibit Specific Questions:

Corn Spinner:

How easy was the gear to turn?

How easy was it to put the corn in?

How easy was it to get the corn out?

Apply the Brakes:

How easy was it to spin the wheel?

How easy was it to move the brake handle?

Box of Rocks:

Was the weight too heavy or too light?

How easy was it to move the weight between pegs?

Turn on the Light:

How easy was the crank to turn?

Was the light bright enough to see?

At the end of class:

Which of the exhibits was your favorite?

Which of the exhibits was your least favorite?

Appendix F: Interview Questions for Digital Interactive

Elizabeth Gilbert:

Would you please introduce yourself and tell us what you do with the NHA currently?

How far back does your family go on Nantucket? What about with the NHA?

What work have you personally done with the Old Mill?

About your husband, John, how was it that he became a miller? How long did he work at the Old Mill? Who did he usually work with?

Would you say that there was some defining moments in his time at the mill, or were things largely run of the mill?

You previously mentioned to us that John trained Tom Miner as a miller. How close are you with him or the other millers at the Old Mill now?

Do you still have a strong connection to the mill?

Do you have any other stories regarding the Old Mill, the NHA or your husband that you'd like to share with us?

What does the Old Mill mean to you personally?

Joe Bedell:

Would you please introduce yourself and tell us what you do with the NHA currently?

How far back does your family go on Nantucket? What about with the NHA?

How long you have you worked on the mill? With the NHA?

Who taught you how to mill?

Who did/do you work with on the mill?

How many mills were there on Nantucket in total?

What happened to the others?

Why is the Old Mill here as opposed to another site on the island?

What role did these mills serve on Nantucket (how important were they)?

Historically, what was ground at the Old Mill? Just corn?

Who built the mill?

Who ran the mill?

When did the NHA acquire the mill?

Did/does the mill operate in the winter? When did/does the mill operate?

What changes have you had to make when running the mill today as compared to the past?

What's your favorite part about working on the mill?

Any good stories of working on the mill? What about with the NHA?

What does the Old Mill mean to you personally?

What comes next for you with regards to the Old Mill, the NHA, and Nantucket?

Karl Wietzel:

Would you please introduce yourself and tell us what you do with the NHA currently?

How far back does your family go on Nantucket? What about with the NHA?

How long you have you worked on the mill? With the NHA?

Who taught you how to mill?

Who did/do you work with on the mill?

How long you have you worked on the old mill?

How did grist mills fit into daily life?

How did people usually power their gristmills?

What role did the miller play in the community?

How important was the mill to the community?

How many communities had mills?

What were the mills used for? Was it just grain and corn?

What's your favorite part about working on the mil?

Any good stories of working the mill? What about with the NHA?

What does the Old Mill mean to you personally?

What comes next for you with regards to the Old Mill, the NHA, and Nantucket?

Tom Miner:

Would you please introduce yourself and tell us what you do with the NHA currently?

How far back does your family go on Nantucket? What about with the NHA?

How long you have you worked on the mill? With the NHA?

Who taught you how to mill?

Who did/do you work with on the mill?

How long you have you worked on the old mill?

How do the gears work at the top floor of the mill?

How does the sifter work?

How do you move the corn?

How do the grindstones work?

How do you choose how many sails to put on while the mill is operating?

How do you put on or take off the sails?

How many millers are there when the mill is in operation? Can you describe what working on the mill is like?

What's your favorite part about working on the mill?

Any good stories of working the mill? What about with the NHA?

What does the Old Mill mean to you personally?

What comes next for you with regards to the Old Mill, the NHA, and Nantucket?

Manny Sylvia:

Would you please introduce yourself and tell us what you do with the NHA currently?

How far back does your family go on Nantucket? What about with the NHA?

How long you have you worked on the mill? With the NHA?

Who taught you how to mill?

Who did/do you work with on the mill?

How many mills were there on Nantucket in total?

What happened to the others?

Why is the Old Mill here as opposed to another site on the island?

What role did these mills serve on Nantucket (how important were they)?

Historically, what was ground at the Old Mill? Just corn?

Who built the mill?

Who ran the mill?

When did the NHA acquire the mill?

Did/does the mill operate in the winter? When did/does the mill operate?

What changes have you had to make when running the mill today as compared to the past?

What's your favorite part about working on the mil?

Any good stories of working on the mill? What about with the NHA?

What does the Old Mill mean to you personally?

What comes next for you with regards to the Old Mill, the NHA, and Nantucket?

Susan Berman:

Would you please introduce yourself and tell us a bit of what you do currently?

How far back does your family go on Nantucket?

What work have you done in the past with the NHA, if any? What about the Old Mill in particular?

What inspired you to write and perform "This Old Mill"?

Can you describe some of your working process behind "This Old Mill"?

Do you have any stories you'd like to share regarding the Old Mill and the NHA?

What does the Old Mill mean to you personally?

What comes next for you with regards to the Old Mill, the NHA, and Nantucket?

Joanne Polster:

Would you please introduce yourself and tell us what you do with the NHA currently?

How far back does your family go on Nantucket? What about with the NHA?

Do you still work at the Old Mill site? How long did you/have you worked at the mill itself?
With the NHA?

How did you get started working on the mill?

How long did/have you worked on the Old Mill?

Who taught you how to mill?

Who did/do you work with on the mill?

What is/was your favorite part about working on the mil?

Any good stories of working on the mill? What about with the NHA?

What does the Old Mill mean to you personally?

What comes next for you with regards to the Old Mill, the NHA, and Nantucket?

Appendix G: Final Survey for Summative Evaluation

Preamble:

Hello! My name is ___ and this is ___ and we are WPI students working with the NHA to create new interactive exhibits for the Old Mill. Part of our project involves building a digital exhibit and asking for visitor feedback. Would you like to interact with our digital exhibit while we take some observations for our research? All observational data are completely anonymous and we do not need any of your personal information.

If the visitors are willing to interact with our exhibit, we will also ask them the following as part of the preamble:

After you interact with the exhibits would you be willing to answer a few questions for us? Like the observations, all survey responses will be completely anonymous and we do not need any of your personal information.

Visitor information: (We will be taking these as observations)

Date of Visit:

Prototype Version: _____

etc.

Number of adults by age: ____

Younger: ____ Male, ____ Female

Middle: ____ Male, ____ Female

Older: ____ Male, ____ Female

Number of children: ____

Toddler: ____ Male, ____ Female

Children: ____ Male, ____ Female

Teen: ____ Male, ____ Female

Do you believe that the digital exhibit's interface was easily navigable and intuitive?

- Yes, it was very easy to use
- Mostly, but there were a few problems
- Mostly not, but there were a few parts that worked well

- Not at all, the interface made no sense
- No opinion

If you had any comments regarding the navigability of the interface, please explain:

Did you like the look and feel of the digital exhibit's interface?

- Yes
- No
- No opinion

If you had any comments regarding the look and feel of the interface, please explain:

How informative was the digital interactive exhibit regarding the Old Mill?

- Very informative
- Informative
- Not very informative
- Not informative at all
- No opinion

Did you have any other comments or concerns regarding our digital exhibit? Please explain: _____

We will also take our own observations of how well the exhibits fit the following criteria, based on how visitors interact with them:

- Multi-user
- Accessible
- Intuitive
- Error Free