Full STEAM Ahead

Developing STEAM Resources

for Families and School Groups

Report submitted to Paula Dias De Brito and Cassandra Tavares from the Museum of London Docklands and to Professors Dominic Golding and Jennifer deWinter from Worcester Polytechnic Institute
22 June 2017

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Abstract

Our team collaborated with the Museum of London Docklands to develop STEAM-based learning resources for families and school groups. We ascertained the current state-of-the-art for STEAM at museums across London, created fifteen activity proposals from gallery exhibits and STEAM learning outcomes, then designed, prototyped, and tested three activities for the museum's activity trolley. Based on this testing, we made several recommendations for future development of family activities. We also developed a resource for KS2 teachers to lead self-directed visits through the galleries with school groups. Finally, we recommended how museum professionals might better integrate STEAM into their museum programs and activities.

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

Acknowledgements

Our team would like to thank several individuals who were imperative in the completion of this project. With the continuous support and guidance provided by our advisors, Professors Dominic Golding and Jennifer deWinter, we were able to form a strong group and take our project beyond expectations.

We would also like to thank Paula Dias De Brito and Cassandra Tavares, for sponsoring our project, as well as the entire Museum of London Learning Department and hosts for welcoming us into the museum family and for sharing with us their passion and enthusiasm for the museum. Also, we would not have been able to complete this project to its full potential without the efforts of Vicky Holmes and Kirsty Sullivan from the Museum of London staff.

Our team would also like to extend our gratitude to everyone who took the time to meet with us, answer our questions, and provide insight for our project throughout this process. This includes the staff of the Royal Institution, specifically Jon Farrow and Peter Gallivan, who welcomed us as volunteers and as observers at the museum's Family Fun Day in May, the staff and students of Thomas Gamuel Primary School, who eagerly participated in the testing of our school resource, and the several staff members at each of the museums we visited during our research here, whose knowledge helped us to better develop our deliverables for this project. Our team truly appreciates everyone who contributed to the successful completion of our project.

Executive Summary

Culture, history, and art-centered museums have begun to increase their focus on STEM learning (Science, Technology, Engineering, and Mathematics). Recently, there has been a greater emphasis on integrating art into STEM, thus creating the STEAM approach (Science, Technology, Engineering, Art, and Mathematics), a more designed-centered approach to science, technology, engineering, and math. Within this context, the Museum of London Docklands (MoL Docklands) is seeking to enhance its use of this innovative method in order to bring a cross-disciplinary approach to the interpretation of its collection.

MoL Docklands is a recently founded social history museum striving to carve out its niche in the museum world. Since its founding in 2003, they have developed a focused exhibit space documenting the River Thames, the development of London's docks, and the people who have inhabited and worked in the area. The collection extends from the mid-1600s to the present, creating a narrative that permeates through the gallery. The museum attracts more than 200,000 visitors per year, and its award-winning school program engages over 25,000 students and teachers.

In general, the museum recognizes that the current text panels in their permanent galleries do not fully explore the importance that science and technology have had on the development of London, the Thames, and the docklands. Working towards these goals, our team came to London to help develop innovative methods for engaging families and school groups in STEAM learning based on the museum's collections. To aid us in our work, we created three overarching objectives to guide our research and development:

- Objective 1: Ascertain the current and best practices for engaging both families and students in STEAM learning in museums,
- Objective 2: Prototype and test activities for the museum's activity trolley[1],
- Objective 3: Prototype and test a teacher resource for school groups.

Our process for achieving Objective 1 was twofold. First, we presented an overview of the broader museum learning community's efforts and perspectives on engaging family and school group audiences. Then, we developed a common framework of goals and terminology which we used throughout all stages of this project. In order to accomplish our goals, we explored the current states of both family and school group learning in museums by considering three different perspectives:

1. MoL Docklands' perspective, including current and past methods used by museums to engage families and school groups;
2. The views and expectations of the families and school groups themselves; and
3. The ways other museums have previously approached STEAM concepts.

Having a working knowledge of these perspectives facilitated our resource design in better engaging and educating visitors in STEAM through the MoL Docklands' collection.

While in London, we sought to expand on our research by conducting visits of eight museums (the Museum of London Docklands, the Museum of London, the National Maritime Museum, the Royal Institution, the Horniman Museum and Gardens, the Science Museum, the

[1] An activity trolley is a mobile table and storage unit that is used to host facilitated activities in museum galleries.

Museum of London Archive, and the Tower Bridge Museum) that have extensive experience working with families and student groups for STEAM learning. While visiting each museum, our team took the opportunity to observe and participate in programs similar to those that MoL Docklands wishes to develop and to collect sample resources that would aid us in the design of our own. Our team also participated as volunteers in a Family Fun Day event hosted by the Royal Institution. This gave us experience running similar activities and was important to reflect on when developing our own activities and volunteer resources.

Upon completion of the tasks outlined in Objective 1, we identified six key themes to categorize our findings. These themes summarize the overarching takeaways that we learned through our museum visits, interviews with volunteers and staff, and through our experience facilitating activities at the Royal Institution. We applied these findings to aid in the development of our resources for Objectives 2 and 3. From this, we concluded:

- Facilitated interactions in museums assist in learning;
- Object handling possesses benefits and pitfalls;
- Personal connections spark understanding;
- Provided information must be adaptable;
- New concepts inspire curiosity; and
- Gallery connections reinforce museum material.

With this new knowledge, we toured MoL Docklands once again in order to derive a list of fifteen possible activities based on different exhibits in the galleries. Our team chose three to prototype for testing on the activity trolley—Puzzle Packing, Ship Shapes through the Ages, and Stinky Sewers. These activities were chosen based on feasibility and on their relatively low level of complexity. Our team developed activities and produced working prototypes and volunteer packs[2]. These prototypes were tested at the MoL Docklands during May Half Term. Upon completion of prototyping and testing, our team presented recommendations for the museum's design team to consider in future development of family activities in general, as well as the three prototype activities. Upon completing our testing, we presented our activity prototypes and recommendations for the future development of family activities. We stressed:

- Proper trolley placement in the museum;
- The need for activities to scale across increasing amounts of people and groups;
- How to overcome language barriers through design;
- Maintaining a strong connection to the galleries; and
- The importance of testing the relevance and adaptability of narratives and background facts.

The third objective of our project covers the design and testing process of a teacher resource pack for school groups. The overall goal of the resource is to create a tool for teachers to use during self-guided tours of the museum. We conducted a preliminary review of the school curriculum for students in the London schooling system from ages seven to eleven, also known as Key Stage 2 (KS2). Based off the findings from Objective 1, the initial review of the KS2

[2] A volunteer pack is a resource for the activity administrator to use while conducting the activity. It contains important facts and background information, an overview of the activity, instructions for running the activity, and possible questions and narratives for the administrator to present to participating families.

curriculum, and a review of additional materials identified in interviews and museum visits, our team created a preliminary design for activities designed to work alongside classroom lessons.

After creating the resource, our team was able to test with a group of 60 students and 6 chaperones from the Thomas Gamuel Primary School. This, however, was too large a group to go through the museum together, so it was split into three groups of 20 students with 2 chaperones each. Each member of our team observed one subgroup interact with the teacher resource throughout the museum. We observed the chaperones' interactions with the students and the students' interactions with each other and the activities. From our observations and from chaperone feedback, we found:

- Retaining student engagement was difficult, but interactions were meaningful when there was focus;
- Students interpreted the resource uniquely in ways we did not expect;
- Students responded positively to new concepts that were well explained;
- Resources should build a coherent a visitor journey through the museum;
- Wayfinding should always be considered in teacher resource designs to aid gallery connections; and,
- Scientific explanations must be concise and entertaining.

Our research and development process guided our group through a comprehensive study and confirmation of how families and schools learn in museums. We saw new opportunities for STEAM fields and the benefits for museums therein. Throughout the entirety of this experience, there were many themes that remained present throughout each objective.

From these findings, we present a collection of general advice directed towards museum professionals looking to integrate STEAM concepts into their museum programs and activities. First, museum professionals should tour their galleries frequently, examining each display for STEAM connections, and maintaining a list of possible activities to develop fully. We also believe activity trolleys are versatile tools that aid in the delivery of family activities in museums. Finally, we encourage the museum community to continue freely sharing ideas to further innovation in these areas.

Authorship

Primary Author: our team member who did the initial writing for the section
First Reviser: our team member who did the first set of revisions on the section, including rewriting and adding new material as necessary
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Introduction

Numerous organizations in the United Kingdom (UK), both public and private, have been promoting engagement with STEM, especially in the primary and secondary school levels. Being highly trusted institutions of learning, museums possess the unique ability to attract and engage a multitude of people from diverse backgrounds. Science museums have successfully been promoting learning and engagement in STEM for many decades. Only recently have culture, history, and art-centered museums begun to increase their focus on STEM learning, which articulates nicely with the increased emphasis on integrating Art into STEM, leading to STEAM. Within this context, the Museum of London Docklands (MoL Docklands) is seeking to enhance its use of this innovative method and bring a cross-disciplinary approach to the interpretation of its collection.

The Museum of London Docklands is a social history museum, which has chosen to carve its niche into the museum community by telling the story of the river Thames, the docks, and the people who lived and worked in these areas. Their collections and galleries are extensive, spanning from the seventeenth century with over 200,000 visitors per year. Additionally, the museum also hosts an award-winning schools program, engaging over 25,000 pupils and teachers per year. The museum wishes to focus their efforts on these two core audience segments.

Engaging both audience segments poses a unique set of challenges and opportunities. The first floor Mudlarks children's gallery offers a tailored experience for families with children up to eight years old. However, the museum is also looking to provide activities for family groups with children between the ages of seven and twelve. By placing STEAM-based activities in various locations across the galleries on an activity trolley, MoL Docklands hopes that families will also be encouraged to more freely experience what the museum has to offer. The museum's current family programs are generally held during school vacation days and term holidays. To complement these with the addition of engaging STEAM-based activities, the museum will be able to have a family offer available every weekend to complement their self-directed resources.

Recently, the galleries have undergone some major changes, including the removal of displays exploring London's history before the eighteenth century. This means that their galleries are now less relevant to the primary school history curriculum, which ends at 1066 AD. If schools cannot connect a museum's galleries to their curriculum, they are less likely to visit. However, these changes have opened up a range of opportunities for the museum to engage with primary schools though the exploration of local history and STEAM curriculum links. Their current provision includes a variety of museum-led STEAM sessions, but they currently do not have enough STEAM resources for teacher-led visits.

In general, MoL Docklands also recognizes that the current text panels in their permanent galleries do not fully explore the importance that science and technology have had on the development of London, particularly in the Docklands. Working towards these goals, we came to London to help develop innovative methods for engaging families and school groups in STEAM learning based on the museum's collections. To aid us in our work, we created three overarching objectives to guide our research and development.

We begin our report by providing a review of relevant literature overviewing the current beliefs of how families and school groups learn in museums. We then outline the methodology for how we confirmed this through hands-on research and for how we achieved objectives 2 and 3. The discussion then moves to an in-depth documentation of the methods and findings from the development of our family activities. Next, we describe our process and findings from developing a school resource for teachers to use with students during their visits to the museum. Finally, we conclude with a set of general recommendations for museum professionals looking to integrate STEAM concepts into a social history environment.

Background: Past and Current Strategies of Families and School Groups in Museums

In this chapter, we present an overview of the broader museum learning community's efforts and perspectives on engaging family and school group audiences, and developed a common framework of goals and terminology that we used throughout all stages of the project.

In order to accomplish our goals, we explored the current states of both family and school group learning in museums by considering three different perspectives:

1. MoL Docklands' perspective, including current and past methods used by museums to engage families and school groups,
2. The views and expectations of the families and school groups themselves,
3. The ways that other museums have previously approached STEAM concepts.

Having a working knowledge of these perspectives facilitated our resource design to better engage and educate visitors in STEAM through the MoL Docklands' collection.

Museums Generalized: Family Learning

For many years, there has been a significant amount of research about how people learn in museums. As part of Theano Moussouri's research for The University of Leicester's Department of Museum Studies, she prepared a document entitled, "A Context for the Development of Learning Outcomes in Museums, Libraries and Archives." In it, Moussouri outlines 5 main approaches that museum professionals take to identify family learning outcomes in their environment.

The original approach was based on three overlapping domains, cognitive, affective, and psychomotor (Figure 1), and 6 levels of each: knowledge, comprehension, application, analysis, synthesis, and evaluation.

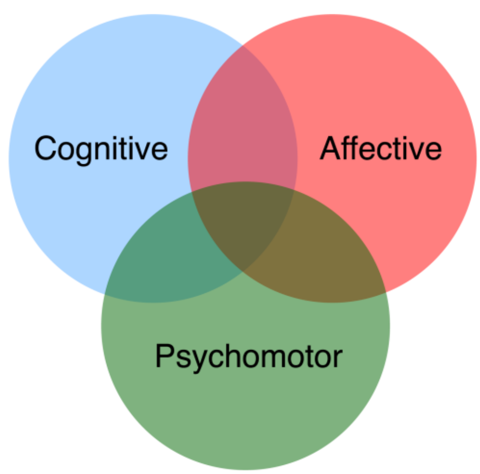

Figure 1: Overlapping Domains of Learning Outcomes

The cognitive domain focuses mainly on a person's ability for reason and to comprehend facts, where the affective domain is based mostly on emotions, attitudes, and values, and the psychomotor domain relates to physical skills and capabilities (Moussouri, 2002).

The second approach was based on the original, but with a greater emphasis on activities based on social needs and human capabilities. The third approach is where things began to shift more to a visitor's point of view rather than human attributes. This learning outcome is child focused and models the desired sequence of events in a child's learning process (Figure 2):

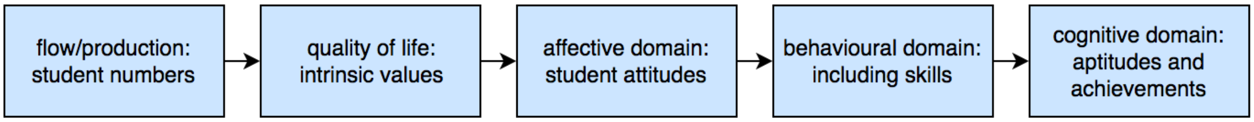

Figure 2: Flow of events in children's learning (Moussouri, 2002, p. 10).

Subsequent learning outcomes were increasingly broader and more holistic. According to Moussouri, the fourth revision had a distinct focus on how societies and organizations help people to fully develop their learning capabilities. This approach, however, did not last long, thus leading to the fifth and most recent framework of learning outcomes, one focused on lifelong learning. This outcome is based on research which observes that intelligent behaviors are affected by environment, ability, motivation, and desires of the individual. With this information, the fifth framework is based on a set of abilities necessary for shaping, adaptation, and selection in any environmental context: practical/know-how learning, emotional intelligence, musical/kinesthetic intelligence, practical intelligence, creative intelligence, social intelligence, and academic intelligence (Moussouri, 2002). At this time, this is the general mindset used when developing activities that encourage learning in museums. However, museums have been known to incorporate elements of many approaches. In our project, we adopted certain elements of the fifth approach, namely practical learning, and creative intelligence. These outcomes applied best to the nature of activities we developed.

Held together by shared experiences and values, a family is a unique group of individuals of different ages and interests that have unprecedented methods of learning. Due to this and their role as a core museum audience, families have become a main focus of museum research (Dierking, 2007). Studies have shown that, rather than content, museums provide families with context about themselves and their culture: "Families themselves function as learning institutions, drawing upon museums as one of the many tools they have to build family identity" (Dierking, 2007). Based on this notion, museum exhibits and programs should aim to encourage families to learn through each other.

This shift naturally affects the testing and evaluation of exhibits and interactive activities. According to Cathleen Donnelly, Exhibit Developer, and Leslie Power, Director of School Services and Family Programs, of the Children's Museum of Indianapolis, exhibits used to be tested and evaluated based on their appeal to children, but with the new notion of families being a learning unit, exhibits are tested and evaluated differently now. This new testing is completely family based, the initial concepts are tested with focus groups comprised of family members of all ages. Interactives are redesigned based on how families interact with each other while using them, the optimal result is to observe families playing and talking together (Dierking, 2007). Based on the observation of families throughout a museum, objects that appear intriguing and seem to encourage family engagement are chosen to use in future exhibits, activities, programs, etc. in an attempt to hold the attention of families. Even the labels have been affected by this new regard of families. The labels are designed to be read aloud: the font style and size chosen with all ages in mind, and the content is intended to aid families in strengthening personal connections (Dierking, 2007). Due to the way this new method engages families, parents are able to work with their children, versus the normal convention of parents imploring their children to do homework. Parents now have the ability to "work alongside their children to do activities and feel comfortable not having all the answers" (Dierking, 2007, p.24). The feedback from parents about such aspects of the new changes has been positive and has proven this new approach to be promising.

Museums Generalized: School Groups

In the past, museums have often been used by schools for extracurricular activities such as field trips. With greater emphasis on curriculum content, time-on-task, materials, and given cuts in school budgets (Figure 4), many schools have reduced the number of or removed field trips from their educational plans (Association of School and College Leaders, 2015). A sense in educational boards among some educational administrators see field trips as unnecessary frills rather than serious learning experiences.

To counter this, museums have tried to tailor their exhibits and offerings to better meet the needs of schools. In order to tie into the curriculum, they have developed pre- and post-visit materials for school groups as well as independent teacher-led, and staff-led, programs and activities at the museum (Braund & Reiss, 2006). These programs, activities, and various resources are designed to ensure teachers are well supported when using the visits to educate their students. Many of these materials are posted, published, and further developed online, where access to the collections may serve as additional classroom resources independent of the museum visits.

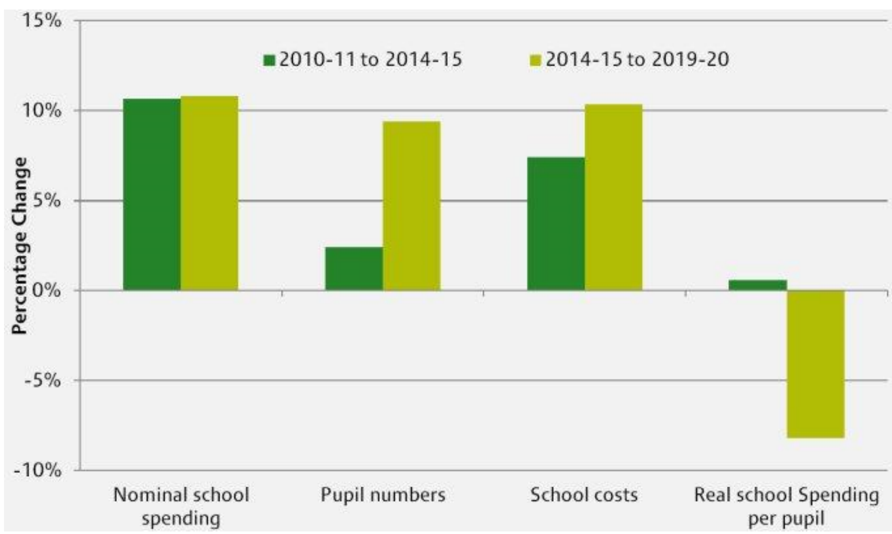

Figure 3: Schools Spending - 2014 to 2019 (Sibieta, 2015)
https://www.ifs.org.uk/publications/8027

Ideas and lessons learned are retained at a higher rate when providing museum visits that include the classroom. By relating the different methods of education there is no gap formed in the mind to separate the experiences. According to a guide made by the Kemper Art Museum, before attending the museum, it is very beneficial to review concepts that will be covered on the tour to start gaining a familiarity with the material. Then, after the visit, by having lessons related to items and exhibits experienced in the museum, the students can continue to strengthen and expand their knowledge of the materials and topics. This allows them much more time to absorb the information instead of just the brief school trip to the museum (Fricke & Taylor, n.d.). As museums work with schools to develop more resources that help transition from the classroom to the museum and back, the line between the two begins to blur and education can continue uninterrupted through both venues.

MoL Docklands and Family Learning

The Museum of London Docklands has many opportunities for family learning; however, few are resources available for everyday family interactions at the museum. The bulk of the museum's family resources take the form of family workshops and programs. Though these programs are successful in attracting families and engaging them in fun, educational activities, there are few implemented resources for families to use during a typical visit that allows them to work together and learn as a family (De Brito, 2017). The MoL Docklands is working on a new resource called 'family backpacks' which is indeed a backpack full of props and activities that encourage families to learn and enjoy the museum together and at their own leisure. (De Brito, 2017) In the past, the MoL Docklands attempted to use an activity trolley with props and objects from the museum exhibits. Unfortunately, the trolley activities did not successfully engage visiting families. The MoL Docklands also tried a craft trolley, which successfully engaged families, but quickly became messy and very difficult to manage (De Brito, 2017). Building on these experiences, the MoL Docklands would like to develop a trolley-based family learning resource that is engaging and family friendly, but also easily managed by staff and volunteers.

MoL Docklands and School Groups

There are numerous ways for school groups to experience the MoL Docklands with varying degrees of museum involvement. School groups have the option to utilize facilitated museum sessions, in-school sessions, and learning resources, all of which can be located through the museum's website. Many of these options offer varying degrees of student involvement as well. The facilitated sessions resemble a lesson plan for students during a museum visit, complete with various activities and writing and reading exercises (Docklands, 2017). The in-school sessions effectively bring the excitement of the stories from the museum to life in the classroom.

These aforementioned facilitated sessions are usually shows or performances that bring to life the museum exhibits and histories for students of all ages to enjoy. The learning resources are also not necessarily intended for use solely in the museum. These are available for students to watch, read, and experience at any time. Many of the resources offered are videos, games, articles, and websites for students to access on their own in order to learn more about the history that the museum displays (Docklands, 2017). Some of the more recent student resources are guided lesson plans with activities for faculty to use with the students during museum visits. Students can either be broken up into groups or remain together when partaking in these guided sessions. In these sessions, students are encouraged to role-play, write about and draw some of what they observe, and experiment with their surroundings—place a pencil on the floor to observe why the slant might have been useful when unloading barrels (Docklands, 2013). The student resources currently available for school groups are varied and educational, however, there are no programs with a distinct focus on STEM. For this reason, the MoL Docklands would benefit from a new academic resource based in STEM that matches their current resources in both its interactive and its educational aspects (De Brito, 2017).

Families in Museums: Expectations and Learning Experiences

Being a dominant audience in museums, family groups have been researched by social scientists and museum learning professionals since the mid-1970s (Dierking, 2007). Research efforts over the past several decades have mainly concentrated on reasons why families visit, expected outcomes, and evaluations of learning (Figure 4):

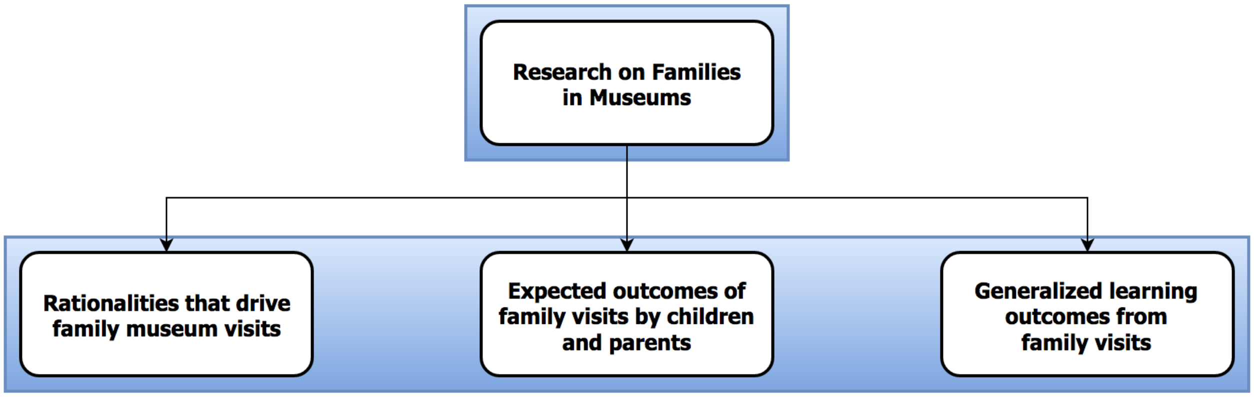

Figure 4: Research on Families in Museums - Topic Breakdown

Families assess many factors when planning a museum outing. According to research done by Kai-Lin Wu at the University of Surrey, parents tended towards options that offer interactive features, which are aligned with the children's age, interests, and learning styles. The aforementioned exhibits lead more often to a pleasant and enjoyable trip (Wu, 2011). Additionally, prior experience is a key force that drives visits. In other words, the more enjoyable that a museum trip has been in the past, the more likely they are to visit again.

One of the primary expectations that families have out of a successful museum visit is the potential for internal discussion within the family unit and to "provide opportunities for family members to reinforce past experiences and family history, and to develop shared understandings" (Dierking, 2007, p. 19). Across several experiments summarized in Dierking et al. (2007), "Researchers have repeatedly shown that many of the conversations that begin in the museum continue once families are back in the home" (p. 21). In a well-designed museum, families also expect to be able to improve their existing family learning dynamics, "giving [parents] an opportunity to step outside their traditional role as homework "dictator," and to instead work alongside their children to do activities and feel comfortable not having all the answers" (Luke, Bronnenkant, & Dierking, 2003, n.p). This illustrates the desire from parents to be able to learn with their children as a cohesive unit.

School Groups in Museums: Expectations and Learning Experiences

The methods by which school students learn in museum environments will be explored in this section. School museum visits, ubiquitous across curricula and geography, have been described by Dierking et al. (2007) as possessing "complex and interdependent relationships among students, teachers, and museums" (p. 31). In this section, we review the literature regarding the justifications for school visits, expected outcomes, and assessments of learning (Figure 5):

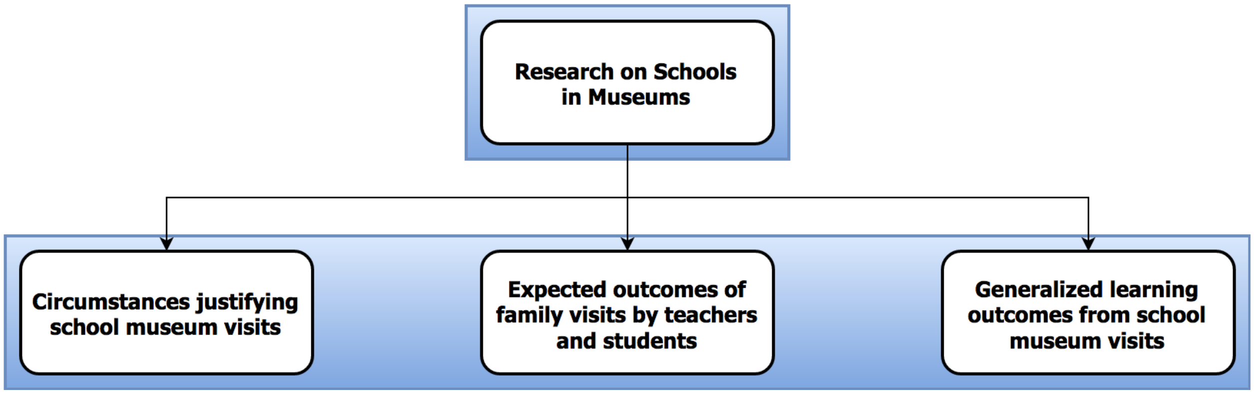

Figure 5: Research on Schools in Museums - Topic Breakdown

Ultimately, due to the nature of a school group visit, the primary impetus for where and when a school group visits a museum lies within the educator. From their perspective, field trips are generally chosen based on what they believe will be educational, age-appropriate, and supportive of curriculum subjects (Tal, Bamberger, & Morag, 2005).

All parties involved in a museum trip possess certain expectations of what outcomes will result. From the student's perspective, Storksdieck (2006) describes how prior experiences and personal opinions largely shape students' preferred outcomes. Some preferences span ages and backgrounds. Dierking et al. (2007) explain: "students declared that learning and enjoyment went hand in hand when it was fun - they had choice and they were with friends and family" (p. 33). Additionally, "students also want it to be a satisfying social occasion when they learn with and from their peers" (Dierking et al. 2007 p.34).

Students not only express preferences for particular museum learning outcomes, but they also express distaste for others. Students were generally averse to worksheet-driven experiences because, according to Randol (2004, p.22), "worksheets tend to narrow the focus of the viewing to only finding the answers in order to complete their assignment rather than using their own curiosity to explore the exhibit." Bamberger and Tal (2005) also found that students expressed displeasure when the museum presented the opportunity for students to make choices in their learning, but they were prevented from making choices by museum guides.

Educators also possess certain expectations and desires for what and how students should be learning on their trips to museums. In the SMILES (School-Museum Integrated Learning Experiences in Science) project, Griffin et al. (1998) found that teachers want to provide students with: (1) a meaningful purpose for the visit; (2) freedom of choice in learning outcomes; and (3) opportunities to take ownership of their museum learning activities.

Unfortunately, "the reality of many field trips involves teachers who visit with few and often poorly defined objectives, little preparation, and loose connections to the classroom unit or curriculum" (Storksdieck 2006, p.31). Dierking et al. (2007) explain that teachers are rarely provided with useful or relevant preparation for taking field trips during the initial training stage of their careers. They generalize that teachers behave in largely the same ways as their predecessors as there are few models available to educators. Ultimately, teachers face stress due to organizational and management concerns, as well as a poor understanding of relevant pedagogical approaches (Falk & Dierking, 2000).

STEAM Education in Museums

Due to their informal learning environment, social history museums have the unique opportunity to engage people in STEAM within the context of culture, art, and history. For this reason, social history museums are beginning to incorporate STEAM concepts into their exhibits and activities with increasing frequency. In a social history environment, STEAM applies more directly rather than STEM due to the way 'A' is defined. 'A' typically stands for Art & Design, which includes the missing human component to STEM fields. Since social history is defined by people's actions, it stands to say that inclusion of a human element provides a more holistic approach to STEM concepts in this new environment.

For example, the Black Country Living Museum (BCLM) is an open-air museum in Dudley, England that portrays life in the period immediately after the industrial revolution (BCLM, 2017). The museum collection spans across multiple buildings in the town, all preserved or restored from the period. As part of their educational resources for families and schools that visit, the BCLM has identified connections to STEAM concepts through chemistry sessions at their interactive pharmacy exhibit (Essex, 2013) and family workshops on product design (BCLM 2017). Through exhibits and activities, the BCLM is able to relate the things that real people of the period did to relevant STEAM topics today.

By collaborating with industry, museums are also able to provide entire environments and gallery spaces that target STEAM-focused family learning. One example of this is the Dow AgroSciences science center at the Children's Museum of Indianapolis. The science center consists of three facilities. Two of them, STEMLab and SciencePort, are spaces where the museum can host family activities and workshops. Additionally, STEMLab has the full facilities of a modern chemistry lab, which allows experiments and demonstrations to be carried out. By leveraging Dow's connections to experts in STEM fields, the Children's Museum is able to bring in scientists and engineers to facilitate these family activities. The third facility is a permanent exhibition at the museum known as ScienceWorks. While being one of the most popular exhibits in the museum, ScienceWorks is also a gallery that allows families to explore the work of real scientists. They get to see how these people use science process skills to ask questions and seek answers to help people's daily lives.

Museums can also choose to bring the gallery activities straight to the classroom. In the Spring of 2016, the Design Museum worked closely with a group of students to create resources that would encourage a design mindset in STEAM subjects (Campagna, Davis, DePlacido, Gaskell, 2016). The resources took the form of classroom activities that relate to the museum's newest exhibit, "Designer, Maker, User". One activity, "Simply Sugru," teaches students functional design concepts by challenging them to fix and improve everyday objects using Sugru putty (Design Museum, 2016). The intended use for the teacher pack is to encapsulate a planned school visit to the museum, leading activities from the pack both before and after the visit. Before the visit, the activities are able to spark interest in the students. This encourages them to seek out specific things in the galleries. After the visit, the students are able to apply what they have learned in the museum to help them complete further classroom activities.

Conclusion

Studies have shown that people do not see learning and entertainment as mutually exclusive, and, for this reason, many view museums as educational organizations (Moussouri, 2002). There are many conditions that facilitate learning, and most, if not all, are found in museums. By interacting with each other and discussing activities and resources, families and school groups are able to learn more extensively. There are many ways like this to facilitate learning in museums, some of these are: establishing personal connections, developing and applying various types of skills, building on past knowledge, and learning within a social context (Moussouri, 2002). The importance of the sense of cultural ownership and the increase in confidence that results from these are invaluable for learning and the overall experience. The most crucial aspect of learning in a museum is the visitor's excitement towards the activity and exhibits. Studies have shown that excitement about an activity produced stronger responses towards it (Moussouri, 2002). Therefore, it was necessary for us to understand the perspectives of families and school groups in museums, in order for us to create exciting, engaging, and educational resources for the MoL Docklands.

Assessment of Current and Best Practices

We determined the current and best practices of engaging students and families in STEAM learning. First, we detailed the intent, methodology, and protocols for interviewing museum staff members will be discussed. Next, we identified the process and protocols regarding the observation of museum activities in practice. Our team followed this with an explanation of how and why our team collected samples of program materials for schools and families. Finally, we describe our participation in the Royal Institution's Family Fun Day. This included the nature of the activities that our team carried out, along with a summary of the protocols we followed while visiting.

Museum Visits

Upon arriving in London, our team consulted with MoL Docklands staff, specifically Cassandra Tavares and Kirsty Sullivan, to clarify their goals and expectations in terms of the activity trolley and interpretative resources for families. This meeting shaped how our team regarded the museum's exhibits, and covered topics such as the programs that the museum had developed already, the generalized learning outcomes that the trolley should promote, and any other assorted expectations that the staff may have regarding how the cart should be administered.

In order to better understand the ways museums engage families and school groups, our team visited eight museums (the Museum of London Docklands, the Museum of London, the National Maritime Museum, the Royal Institution, the Horniman Museum and Gardens, the Science Museum, the Museum of London Archive, and the Tower Bridge Museum) throughout London that have extensive experience working with families and student groups for STEAM learning. These visits consisted of both directed and self-guided tours through the museums and informal interviews[3] with museum volunteers and staff. The interviews were semi-structured, qualitative, and conducted in person with a scribe to record key points. Audio recordings were not taken in order to more easily adhere to privacy guidelines. The topics covered in each interview were largely centered around what activity formats engage families and school groups the most, how intended learning outcomes shape the design of an activity, what activities and strategies have proved successful and which have not, and overall recommendations for developing STEAM activities and resources for families and school groups. Each interviewee was presented with a short verbal statement, or preamble, explaining their right to review all notes taken, their right to anonymity if attributed in the final publication, and the nature of our team's research (See Appendix A).

Experience Program Delivery

While visiting each museum, our team took the opportunity to observe and to participate in programs similar to those that the Museum of London Docklands wishes to develop. By experiencing these activities, our team was able to develop a better understanding of what aspects of each activity successfully engaged families and students. Our team was also able to identify activity formats to avoid and ones draw inspiration from. During these visits, our team took note of several factors, including but not limited to what objects on each trolley are used most and least and important topics of conversation between family members or students and the

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[3] A formal interview was conducted with Frazer Swift, Head of Learning at the Museum of London, the full outline of proposed questions for this interview can be found in Appendix A.

person running the trolley. Museum staff explained to all groups that our team members were merely observing as part of a research project on family and student learning. Our team solely observed groups under the direct supervision of museum staff, and did not survey or photograph participants, interact with children, or collect any identifying information.

Samples of Program Materials

Each museum visit provided us with an opportunity to collect sample materials as models for the design of both the volunteer packs and the teacher resource (see Appendices C and D). Our team also obtained copies of family activity trails from some of the museums visited and the teacher resources developed by the museum's school learning staff. Sample resources collected from multiple museums were be cross-referenced to identify similar design principles and the key components that lead to an effective resource. Overall, these resources allowed our team to move past ineffective designs and to build from those that have proven to be successful.

Family Fun Day at the Royal Institution

Our team participated as volunteers in a Family Fun Day event hosted by the Royal Institution. Three times per year, the Royal Institution hosts an extensive set of short talks, experiments, demonstrations, and creative activities directed towards families. The subject of each event's activities is designed around the established theme of that event. This Family Fun Day was titled, "The Chemistry of Life," and hosted activities pertaining to the discipline of biochemistry. During this visit, we participated alongside other volunteers, using volunteer packs to assist them as they administered activities in the morning. During the afternoon, our team took the opportunity to observe families interacting with the activities and presenters. Our team noted several factors, including but not limited to what activity sessions are attended the most or least, and noting important conversation topics and learning outcomes exchanged between family members and the volunteer staff administering the activity. Since this visit involved being present amongst visiting children, our team did not survey participants or interact with children except as supervised by museum staff. As an additional measure, our team reviewed the Royal Institution's museum policies before the visit, and attended a training session that is mandatory for all volunteers. During the training, the Royal Institution's expectations and guidelines for what could and could not be done was more clearly outlined.

Key Themes and Findings from Museum Research

Upon completion of our tasks outlined in objective 1, we identified six key themes to categorize our findings. These categories summarize the overarching takeaways that we learned through our museum visits, interviews with volunteers & staff, and our experience facilitating activities at the Royal Institution. We finally applied these themes and findings to aid in the development of our resources for objectives 2 and 3.

Importance of Facilitated Interaction

Through our museum visits, we were able to observe, experience, and lead facilitated interactions with families. From observing the Horniman's engage zones, we saw how volunteers played a significant role in encouraging families to interact with the trolley activities, along with the galleries in general. This was achieved through the variety of questions volunteers could ask, along with the many stories and facts that were prepared for each activity.

At the Science Museum's Wonderlab gallery, certain facilitators called "Explainers" were placed to guide families through the different interactives. They commonly built narratives using questions and facts to keep families engaged through their gallery experience. They also showed families how to interact with the displays and -games if they had any questions. We noticed that families would typically spend an entire visitor journey with one Explainer in tow. This illustrates how families gravitate towards facilitators when presented with the opportunity.

In summary, facilitated activities have the ability to reach families in ways that text panels and self-guided activities simply cannot. Activity facilitators have the ability to add emotion, narrative, and structure to a museum experience. For these reasons, we chose to emphasize interaction with families in our gallery activities.

Benefits & Pitfalls of Object Handling

While observing family activity trolleys at the Horniman Museum and the Museum of London, we were able to identify the advantages and disadvantages of a common activity type: object handling. Object handling activities allow visitors to directly touch and examine artifacts and historical items. Activity facilitators typically ask families guided questions about their observations, along with a narrative explaining the story behind the objects. From our notes, we identified that this style of activity engaged families, giving them the ability to have meaningful conversations about the learning outcomes, and to create personal connections to history. We also noted that while some object handling sessions implemented simple activities like matching and timelines, most sessions had similar delivery styles to the one mentioned initially. This would limit us creatively in the future if we solely designed object handling activities. Our sponsors also identified that obtaining objects to display on our trolley would be difficult from a logistical standpoint. For these reasons, we decided not to explore object handling delivery methods on our trolley.

Personal Connections Spark Understanding

From our initial background research on family learning in museums, we learned that families more effectively retained concepts if they could connect it to some aspect of their lives. During our museum visits, we were delighted to finally confirm these findings with similar ones of our own. One example of this came from our time at the Royal Institution. There, we observed families connecting the content of our activities to the professions of their parents or relatives. Through our observations of veteran volunteers at the Royal Institution, we noted how they commonly asked families questions about their favorite hobbies and activities. Children enjoyed when the volunteers could connect the scientific concepts to something they already knew intuitively or subconsciously.

Our interview with Natalie Cain at the Tower Bridge Museum revealed an especially informative anecdote. One child initially claimed to be unfamiliar with how pistons operated when learning about the bridge's bastille mechanism. After a classmate mentioned how the operation of the bridge's pistons is similar to their functionality in the video game *Minecraft*, the initially confused student quickly connected the two observations and finally understood the concept.

These findings significantly shaped how we delivered activities during the testing phases of our project. While many families already express tendencies to make personal connections to learning material, we also find that volunteers should look for opportunities to connect an activity to a family's personal life as well.

Adaptability of Provided Information

Our research also pointed to the importance of adaptability of provided information. This meant that the volunteer packs needed to contain enough information to allow adaptability based on groups' learning styles and the person running the activity's comfort level. Each family learns differently and shows interest in different aspects of the materials. By giving a comprehensive background in the volunteer packets, it gives families the opportunities to delve deeper into the topics of their choice. This allows each group to engage in ways most beneficial for their learning styles and interests; however, the families cannot get this information without someone running the activity. When designing the packets, it was also important to take into account different styles of teaching and interaction with the materials. Some volunteers or staff members may have certain background knowledge that others lack, giving them an advanced grasp on certain concepts; however, a member who did not know the material previously may feel uncomfortable with presenting it to families. The packs, because of this, were designed to explain all the concepts for the volunteers and give many aspect, such as narratives or fun facts, for them to use if they were comfortable. While participating as volunteers for the Royal Institute's Family Fun Day, we found that it was easier, as the day went on, to delve deeper into the concepts due to our growing understanding of the material. By giving different levels of depth on the packets, it allowed volunteers to adapt as they felt prepared.

New Concepts Inspire Curiosity

Another key fact take away from our research was that new and unknown concepts inspire curiosity in guests. If they are familiar with the item or topic they are less likely to stop than if something unknown catches their eye. Artifacts and object handling sessions exemplified this fact the most. If there was an object that looked very abstract, it sparked questions about what it was, what it was used for, and/or when it was made. The sense of the unknown created other questions that furthered conversations. If an object was obvious and immediately identifiable and explainable, then there is no desire or need for further conversation; however, the unknown extends beyond just physical artifacts. While working through an interactive activity, asking questions about why something happens or what they think leads to questioning and more in depth analysis. When given a fact, it is easy to just take it and accept it, but when asked questions it pushes one to look deeper into the background of the facts.

Importance of Gallery Connections

Finally, one of the most important takeaways we had was the importance of gallery connections. When designing activities, whether it is targeted for families or schools, if the activity or resource takes place in the museum, it is essential that it ties into the surrounding exhibits. If there is not a clear and guided connection between the two, the activities can come across as forced, distracting, or detrimental to the visitor experience as a whole. By tying the activities in with the gallery there are connections the activity can point out to further visitor learning and experience. This means the placement of the trolley would be very important. If the trolley is in a location where it ties in with none of the exhibits it is harder to create a cohesive experience when coming to and from the trolley.

Family Activity Development

After ascertaining the current state of the art for STEAM integration in museums, we immediately moved into developing our trolley activities. We first discussed our methods for identifying potential family activities for prototyping. We then described the general methodology for how activities were selected. Next, we reviewed the principal considerations behind our prototyping methodologies. Penultimately, we explained in detail the prototyping, testing, and findings for our three activity prototypes. We then concluded with a collection of key themes and recommendations from this process.

Identifying Potential Family Activities

When going through the museum to evaluate the exhibits, our team took care to evaluate the STEAM based connections that could relate to each exhibit. By approaching the activity design from an exhibit point, it allowed the flexibility to develop learning outcomes as the activity came to fruition. When coming into the gallery with a predetermined outcome in mind it became very difficult to force connections with an exhibit. This freedom of activity adaptability lead to numerous activities that did not seem to connect to STEM or STEAM at first; however, while looking at each activity, prominent STEAM connections appeared and strengthened the activities. Through the gallery tour, we came up with an activity or two for every display. After the initial review of the possible activities, we narrowed our list down to a group of fifteen activities that were feasible and practical to use in the galleries. There were three main factors, among numerous others, when choosing which activity would make the shortlist. First, the activity had to tie into the exhibits around it and be contained and non-damaging. This meant no water, creation of mess, or markers to ensure the safety of the exhibits. The connections to the exhibit would be approached by the member running the activity or by the guests drawing their own conclusions. Next, the activity had to have a strong STEAM emphasis that touched on multiple branches of STEAM and have learning outcomes to match. If the activity was too pointed on one branch or had weak connections to STEAM, it was deemed to be not a practical choice and was eliminated. The activities had to be considered for feasibility in a museum setting and for our development. If an activity was sprawling or needed advanced equipment, it would not be the best in terms of practicality. Also, if materials required for the activity were expensive or not feasible to work with, the activity would not be considered.

Table 1: Chart Detailing 15 Possible Activities

Name of Activity	Activity Description	Learning Outcomes	STEAM connections
Aging and Preservation	Looking at what the museum does to preserve items and why London is such a good place for archeological finds	Understanding of artifact preservation and the challenges that museums face when designing exhibits around these limitations	Science
Blacksmith's Forge	Exploring properties of metal and how people manipulated metals.	Phases of materials. Facts and characteristics of metals	Engineering
Communication	Learning about and testing different methods of communication throughout history	Ways to improve communication through the engineering design process	Science Technology
Frost Fairs	Learn about bridges and their interaction with river flow	Bridges role in a greater system of the river	Science Technology Engineering
Hats	Families Design hats out of different materials for different jobs or situations	Learning about the process behind planning out and designing different items. They will look at what sort of considerations must be made when choosing materials and how to design to a specific challenge	Technology Art
Material Analysis	Play the role of a port tally clerk or tester checking goods	Teamwork and the scientific method	Science Technology
Navigation	Learning about and testing different methods of navigational tools throughout history	Navigation through the ages and required accuracy of tracking and navigation	Science Technology Math
Packing Puzzle	Packing a ship with different goods. Certain rules about goods being next to each other	Strategic thinking, empathy for dock workers, hypothesizing and observation. Understanding of cargo restrictions	Science Engineering Math
Pluto Pipelines	Mapping a route for the PLUTO pipelines to get across the English Channel	purpose of the PLUTO pipelines, and how they assisted the Allied forces in WWII. Also focuses on developing families' spatial thinking	Technology Math
Sails	Families will look at and test the different styles, shapes, and materials of sails. Discussion of different types of sails and their uses.	Knowledge of how sails interact with the wind and how they redirect the air to exert force forwards on the ship depending on their design. Using the design proccess to find the best solution for a specific situation	Science Engineering

Ship Shapes	Analyzing how the shape of a ship's hull affects its interaction with water	How the deformation of water affects ships' movement. Considerations that designers and engineers must make when designing ships in the design method of prototyping, testing, and revising.	Science Technology Engineering
Slide Rule and Calipers	Determining the tax on goods of barrels without opening the barrel	Basic knowledge of volume and a general understanding of taxation	Science Math
Stinky Sewers	Families work together to design and test their own sewer systems	Creatively and collaboratively building structures and shapes. Appreciation of the London sewers from an engineering perspective	Science Technology Math
Swords	Put together swords with different pieces. Talk about what type of sword was used in different situations. What roles on the ship would each one have	Uses of different types of metals and the ways of working them.	Technology Art
Tool Analysis	Look at the materials different goods were packed in and the tools used to manipulate said packaging and containers	The importance of practical packaging and handling of goods. The use of simple machines every day and how it makes our lives easier	Science Technology Engineering

Of the fifteen possible activities described above, we chose three to prototype for testing on the activity trolley—Puzzle Packing, Ship Shapes Through the Ages, and Stinky Sewers. These activities were chosen based on feasibility and on their relatively low level of complexity. We developed activities, produced working prototypes and volunteer packs. These prototypes were tested at the MoL Docklands during May Half Term. Upon completion of prototyping and testing, we presented thoughtfully developed recommendations for the museum's design team.

General Method for Prototype Construction

In order to construct prototypes of the activities for the trolley, our team had to take several factors into account. Due to the time constraint of the project, the prototypes could only be constructed using readily available materials and tools. Without access to a workshop, we had to work with materials that did not require the extensive use of tools. Since the activity trolley is placed in the galleries, the activities could not create a mess or contain anything potentially harmful to the exhibits, such as water. In addition to these stipulations, we were also restricted by a budget for development.

For all activities, we created volunteer packs with the purpose of explaining to any member of museum staff how to run a given activity with families (Appendix G). An additional goal associated with the packs was to explain any scientific concepts to the volunteers that may need to be taught to families. Not all volunteers will have a background in STEM, but this should not be considered a barrier to anyone who wishes to run the activity with families. As such, these explanations were made to be simple, avoid unexplained jargon, and build off of basic definitions that are common amongst people from all educational backgrounds and foci.

General Method for Prototype Testing

The testing of the activity trolley prototypes took place during May Half Term—1 June to 3 June. The museum's theme for this year's May Half Term is Engineering, so this was the opportune time to debut the STEAM based activity trolley prototype. The half-term break attracts a large number of families which provided plenty of opportunities for feedback and observation.

Before any testing could commence, our team determined locations for the prototype. This was done by consulting with the museum staff about practicality, convenience, and quantity of visitors in the area. Appropriate signage was posted according to museum protocols prompting visitors to engage in the activities on the trolley and informing them about the testing in progress (Appendix E).

The activity was run by two team members while the third recorded observations. In order to evaluate the volunteer packs, we each were kept unaware of the information in the pack for one of the activities. Each member was presented with that volunteer pack the day of testing and asked to perform the activity with families. Observations of families using the activity trolley and of use of the volunteer packs were based on the forms found in Appendix D. Our team recorded what most engaged families, encouraged conversation, prompted learning, and what does not, as well as overall usage of the trolley for each activity.

In all forms of pedagogy, verifying the successful transfer of learning outcomes is always a difficult undertaking. In this activity, this was done by asking directed questions towards families about certain scientific and historical concepts while carrying out the activity. This would always happen sometime after the tested concept was initially explained, plus some time for the concepts to be cemented through the hands-on activity.

Upon interaction with the activity trolley, adult members of families were asked if they would like to answer questions detailing their feelings about the experience. We selected internal comment cards rather than a survey due to the ease of filling out a comment card in comparison to a full survey. Since an internal comment card can be shorthand and require little effort in coding/interpretation, the amount of time taken away from administering the activity is minimized, therefore it is much more flexible and practical for use in a busy museum festival environment. After this week of testing, we made the final modifications of the activity trolley activities, and finalized our recommendations for the staff and the design team.

Figure 7: Activity Trolley

Packing Puzzle Prototype

Activity Overview

In this activity, families are prompted through instructions, questions, and facts to design the floorplan of a ship by fitting various tiles into a ship outline. There are two mats with ship outlines on them—the upper level and the lower level, which is a bit smaller. Based on the level of difficulty, the mats can be used separately or in correlation with each other to represent the different floors of the same ship.

STEAM Principles and Learning Outcomes

The Packing Puzzle activity is designed for children and families to gain practice with strategic thinking, empathy for the dockworkers and their knowledge, confidence in their own intellectual and motor skills, scientific hypothesizing and observing, and understanding of cargo restrictions. Packing Puzzle is intended to explore the science, engineering, and mathematics parts of STEAM. Families practice science when hypothesizing about and observing the restrictions of certain types of cargo. The engineering aspect comes from overcoming the challenges presented when packing cargo, especially with the higher levels of difficulty. The highest level of difficulty allows for the mathematics topic to be covered since families have to visualize the multiple levels of the ship while packing the ship. These STEAM topics would only be conveyed if the user is guided through the activity in such a way that introduces each topic.

Required Materials

This activity is composed of cargo and room tiles, two floor plan mats, a volunteer pack, and a list of tile placement restrictions. For the prototype, the tiles were composed of three layers of foam board; some tiles have different goods actually in them, and therefore required a layer of plastic that covers the cutout section of the foam board. For future development, we recommend that the tiles be made out of a sturdier material such as plastic or wood, and that the scented tiles are created using essential oils rather than spices to prevent possible allergy problems. The other materials are made from paper, and for the future we recommend that this paper be laminated in order to extend the activity lifespan and prevent possible damage.

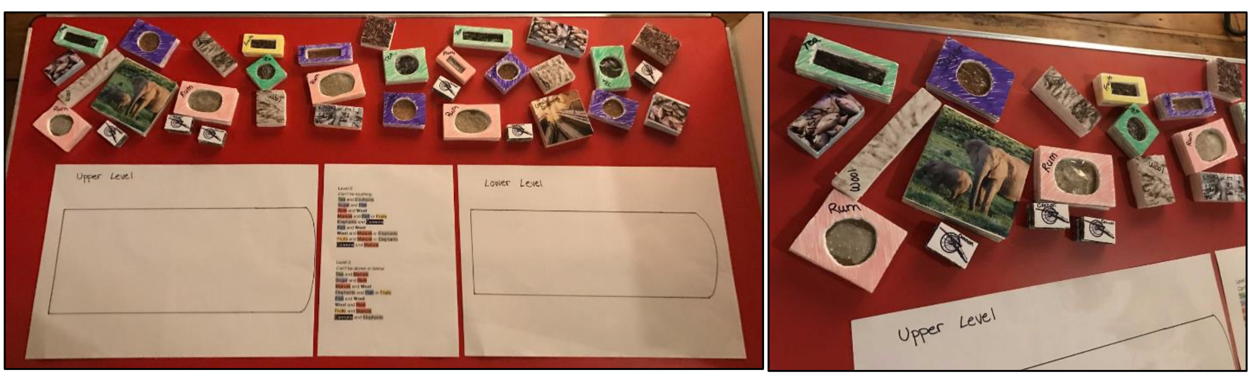


Figure 8: Materials for Packing Puzzle

Group Size and Total Time

On average, families tended to stay for 15-20 minutes to complete this activity. There were, however, several families that chose to stay for significantly longer, up to about 30-40 minutes. During testing, we discovered that this activity is scalable for larger and more groups. Though this activity works well for a small group, it performs equally as well for multiple groups and for larger groups. In the first day of testing this activity, a group of 20 children participated in this activity and were able to work together to complete the tasks and learn about ship packing (members of this group participating in the activity are depicted in Figure 9 below).

Figure 9: School Group Participating in Packing Puzzle Activity

Detailed Summary of Activity

Packing Puzzles was inspired by ship packing plans found in the Port and River Archive at MoL Docklands and by a ship model on in the third-floor galleries (Figure 10).

This activity has three levels of difficulty: **easy** requires the user to fit as many tiles as possible into the outline on one of the mats; **medium** has the user fit tiles into the outline on one of the mats while following the rules for what cannot be touching; and **hard** uses both mats together and requires the user to follow the rules for what cannot be touching as well as for what cannot be above or below each other.

For this reason, the volunteer pack must be user friendly and provide the information to guide the activity successfully. Observation and feedback showed that the volunteer pack was both user friendly and useful for helping the volunteer guide the activity and incite thoughtful discussions. This conclusion was confirmed by a volunteer who is used to working with families and children in the museum.

Family Response

With the volunteer pack as a guide, the activity was run with families during their visit to the Museum of London Docklands in May Half Term. The response from families was completely positive. Observation and presentation of the activity proved that the activity was working in the intended ways and inciting the intended discussions and outcomes.

As seen in the images below, some groups used the tiles in unexpected ways during the activity. Many groups attempted to stack the tiles on top of each other to portray a multilevel component rather than only using the two outlines. Based on this, we ran the activity several times with this being allowed; however, this method of presenting the activity proved too complex and confusing due to the shapes and rules of the tiles. For this reason, we recommend against the stacking component with a clearer explanation of the multilevel component already in the activity.

Another unexpected aspect with testing this activity was running it with a group that spoke only French besides the chaperone. The activity was explained to the chaperone, who then explained it to the children. The chaperone then left and walked around the galleries while the children were participating in the activity. Since we could not further explain the activity to them to work them through it, we found it difficult to tell whether or not the desired outcomes were achieved; however, the moderately successful use of the activity through a language barrier was apparent. Packing Puzzle was also able to scale quite well for large groups as seen in Figures 9 and 11. Due to permission issues, we were not able to photograph any families participating in this activity.

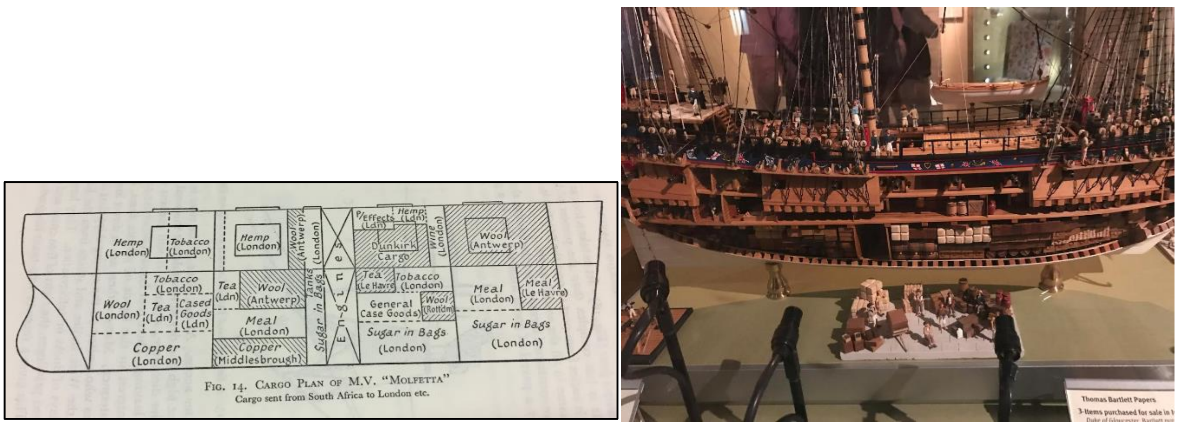


Figure 10: Puzzle Packing Inspirations

Figure 11: Children Stacking Tiles in Packing Puzzle Activity

Ship Shapes Through the Ages Prototype

Activity Overview

While working through the activity the families will look at different ship hull types, looking at different characteristics of each, such as stability and speed, and deciding why certain shapes would be used for different vessels. By testing them in a water analogue they learn about features such as stability and speed of the resulting ships. The activity is designed for families and children to learn about the scientific concepts surrounding ships hull's interactions with water and to analyze different unique shapes based off known examples of ships throughout history.

STEAM Principles and Learning Outcomes

In Ship Shapes Through the Ages families use scientific observation to look at fluid dynamics and interaction of the hulls with the ribbon based water analogue. They are able to see the deformation of the ribbons around the bow of the ships simulating how easy it would be for that shape to move through the water. Through the activity families were presented with different design challenges and were tasked to create different types of ships for these situations. While building their own ships they stepped into the shoes of a designer or engineer and followed the standard design method of prototyping, testing, and revising. They had to think about the multiple iterations made when testing yielded unexpected results.

Finally, the activity included a more arts-focused aspect. This came in the building of the ships and the sketching and expansion of their ship designs. The families were able to take this drawing with them which hopefully inspires them to further explore how different shapes can affect movement in a fluid and continue conversation after the activity.

Required Materials

For this activity, we required a test frame for the water, pre-built models of ships, and blocks in which to build new ships. Originally, the testing frame was going to be built out of wood and be mounted vertically. The ribbons would be kept in place with weights at the bottom of each ribbon. This was intended to create a feeling of moving through the water as the ribbons would bunch up around the hulls while passing them through; however, due to the limitations surrounding materials and tools, we had to decide on another method to build the testing frame. For this, we used a large storage container made of plastic. By cutting evenly spaced slots into the top edge, ribbons could be held in place with simple knots. To maintain tension while in a horizontal position, the ribbons were held by rubber bands attached to the opposite side. These rubber bands all connected to a single ribbon which could be tightened to pull all the ribbons at the same time. While using the single ribbon at the bottom made setting up the activity much easier, the single tightening option did not allow for manipulation of each ribbon individually. This meant that some of the ribbons started to droop and loosen over time. If rebuilt with a wooden frame for future development, each ribbon should be attached individually. If the ribbon is mounted on one end with a screw hook, to tighten the ribbon, and a rotating connector, such as those used on fishing lines, so the ribbon does not tangle, this would allow loose or broken ribbons to be tightened or replaced easily.

Figure 12: Original Design Drawing and Final Prototype for Ship Shapes

While going through the gallery we chose three hull shapes that exemplified the entire spectrum or hull shapes. We chose a rowing ship, which is pointed and very thin, a steamship, which is wide and blunt, and a tea clipper, which is pointed but still wide. These ships were built out of layered foam board glued together to form a thicker ship hull. These hulls then had a handle inserted in them, allowing them to be tested in the water without fingers interfering with the ribbons and outer profile of the ships. The handles being removable had the added benefit of allowing the activity to be easily packed away into the box the testing frame was built in.

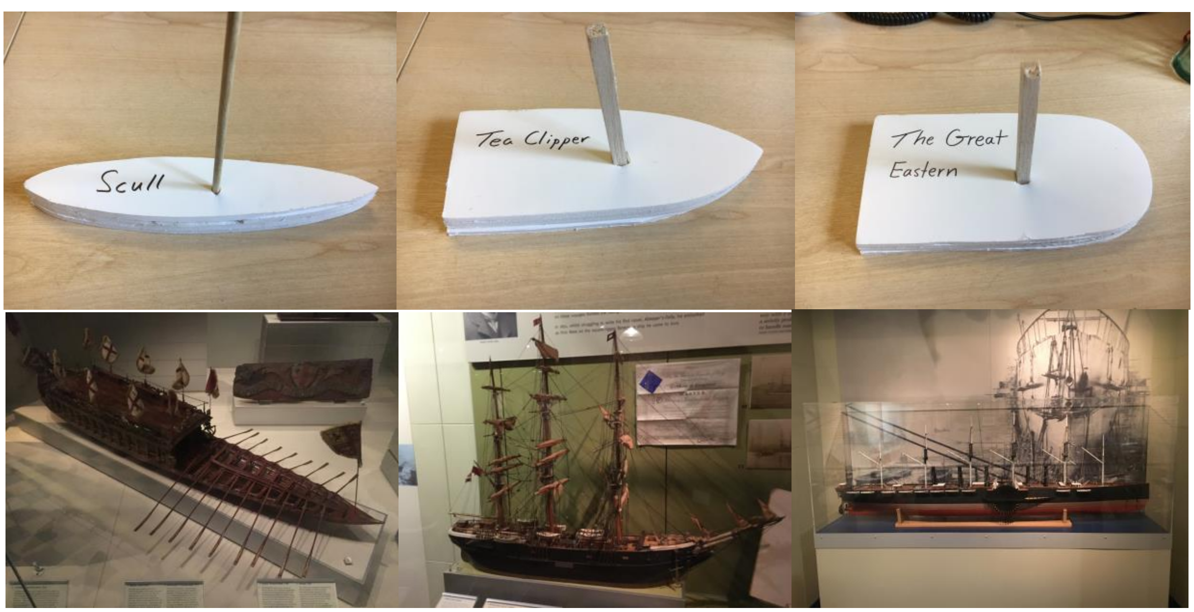


Figure 13: Three Ship Models and their Gallery Inspirations

In order to build their own ships, we supplied the families with blocks with Velcro on them. These blocks could be arranged in multiple orientations to make a ship shape they desired.

When buying materials, we were only able to find normal Velcro, having two different sides, instead of our intended anti snag Velcro which will stick to itself. The anti-snag Velcro would allow every surface face to be totally covered with the same type of fastener because it would not matter what orientation the Velcro or the pieces were in. With the hook and loop Velcro that we used, we had to use a patchwork of alternating hook and loop squares. This lead to different pieces being unable to adhere to each other in certain orientations. When the pieces did stick to each other, however, this style of Velcro was very strong. The bond between the pieces of Velcro were stronger than the bond between the Velcro and the foam. Throughout the activity, we had to replace the Velcro numerous times because they kept being pulled off. In a future iteration, blocks made out of a different, more sturdy material, which adheres to the Velcro solidly is highly recommended.

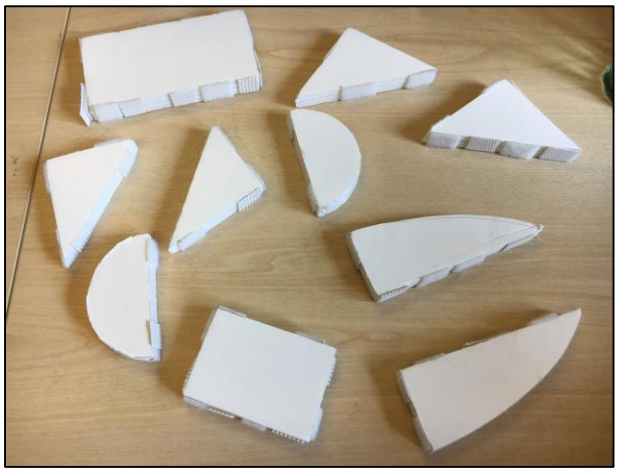


Figure 14: Velcro Blocks to Build New Ships

When testing the step of the activity containing the self-designed ships we found there was a limitation stemming from the number and variety of blocks in which to work. In order to allow a greatly expanded design horizon, we brought paper and writing utensils to trace or draw their own ships. This allowed a greater freedom for them to explore different concepts of shapes in the water and to continue the conversation through the rest of the museum and at home.

To accompany our physical developed resources, we created an information packet for the volunteer to run the activity. This included narratives such as pretending you are a ship designer and you were hired by a rich family wanting you to design a ship to move their goods across their many owned company locations. These stories allowed families to step into the shoes of someone from that era designing ships. The pack also explained learning outcomes and takeaways from the activity as well as descriptions and definitions for scientific facts and concepts. These descriptions went in depth while keeping the language simpler or at least explaining the more complicated words. This opens facilitators up to the material who may have not had a background in the field and allows them to feel more comfortable when delivering these facts to guests.

Detailed Summary

This activity consists of a testing frame, simulating the surface of water, a set of ship hulls, each with different characteristics, and a number of shapes with Velcro on them. To start the activity, the three ship designs are tested in the frame. Each shape corresponds to the shape of a ship present in the gallery. While testing the shapes, the uses of each ship and stories of their history were told to the families in order to increase the immersive qualities of the overall experience. Children in the families seemed to be the most engaged when the models of the ships throughout the gallery were pointed out and they were able to make the connections between the shapes they were holding and the exhibits they saw.

To test the different hulls, first the shapes were placed flat upon the ribbons. This lead to a discussion about how wider and larger shapes are more stable and less likely to sink in a storm. This meant a more reliable ship whereas a small thin ship is easy to sink in a storm. They also noticed, or speculated, that larger ships sat lower in the water. This lead to discussions of why this would make a difference for where the ships could go. One such example they mentioned were issues making it up a river or in shallow areas as well as hazards not prevalent for other smaller ships. Next, the shapes were inserted point first into the ribbons in a way so that they move ribbons out of the way to either side as if the bow was cutting through the water. The smallest point of the ship designs, the rowing boat, moved the ribbons on either side out of the way and easily slid through. Then, for contrast, the Great Eastern was tested. This hull shape pushed a lot of ribbons down but did not move any out of the way. Before testing the final shape, we found it was beneficial, to reengage the children, to ask what they thought would happen before it was tested. They tended to come up with the correct answer and accurately predict what happens where the ship's bow would move a couple of ribbons out of the way but mostly cut through. After having a chance to feel how the different shapes reacted when moving through the ribbons the guests were prompted to think about why they would need certain types of ships for different reasons. For example, why would they not just use lots and lots of fast small ships? Multiple answers can be brought up and were by the guests, such as larger ships are more reliable and fuel efficient, or that it takes less crew for a larger cargo on a steam ship.

After evaluating the shapes of the hulls the families were invited to design and build their own ships out of the Velcro blocks based off different prompts and challenges. Then, the families could trace their creations or draw their own to further their conversations through the galleries and outside of the museum.


Figure 15: Families Interacting with Ship Shapes

Testing and Recommendations

While testing, due to the limited pieces, some of the prompts always ended up with the same design across multiple families. The limit also led to occasional repeats within groups. This lead to the clear conclusion that for future iterations there would need to be more blocks for families to use. A larger variation in block type, and multiple sets and iterations of the same blocks, could lead to increased variety and creativity in ship designs. The activity, in its current form, was very difficult for multiple families to interact with. If one family was using the blocks to build their ships, there were not enough remaining blocks for another group to also participate. This deterred some groups probably in the belief that there was no space available for them.

The takeaway at the end, where the families were able to trace or draw their own ship, was always exciting for them even if they had struggled to comprehend some of the concepts throughout the activity. As previously stated, it allowed a greater freedom to explore the concepts in a slightly different way. It also allowed certain members, if disinterested, to do something else while others are working with the blocks. If drawing their own ships talking to them about what type, they had was a nice tie-in to the rest of the activity.

For future iterations, it would be beneficial to incorporate modern ship hull shapes at the end of the activity, such as, catamarans and hydrofoils. They can move larger ship hulls at high speeds due to the fact that the water touching the "wings" of the catamaran react as if it was a thin fast boat. Talking about the future of faster ships and different designs for ships, such as designs to increase their fuel efficiency by reducing water drag, can spark interesting conversations about moving forward into the future of transportation. Simple conversations such as these can spark interest for the rest of their lives.

When testing, we found that some of our more in depth learning outcomes only came across through guidance of the volunteer. When attempting to have a group go through the activity with little to no guidance, the concepts and reasoning were lacking in substance or backing, but the final conclusions drawn, whether by coincidence or by prior knowledge, were the same as the intended overarching outcomes. This means that the activity is understandable and commutable to an audience, such as toddlers, that may not have fully developed comprehensive skills or for people who speak different languages.

While testing the activities, we had the opportunity to show a volunteer an initial draft of the volunteer pack. She mentioned that the children would probably understand the concepts better than her due to her specific background. This lead to modifications of the pack to more clearly lay out the steps of the activity, what each step should reveal, and what sort of questions and conversations it should start. We also added more understandable and explained versions of scientific concepts to allow the volunteers to be more comfortable with the materials.

Stinky Sewers Prototype

Activity Overview

The Stinky Sewers activity is designed for children and families to exercise their spatial perception skills, learn the root principles of designing and revising, along with basic physics concepts. The activity also shows that science, technology, and engineering is accessible, rewarding, and fun. During the course of their time spent at the trolley, families are prompted through stories, questions, and facts to learn how sewer systems work by designing and revising their own using the pipes, connectors, and terminals provided.

STEAM Principles and Learning Outcomes

Stinky Sewers is intended to explore the science, technology, and engineering aspects of STEAM. Families practice science when hypothesizing and observing the behavior of the marbles inside their PVC pipe network. It also provides an opportunity for the facilitator to explain the simple physics behind why water cannot flow above the starting point of a sewer system, which leads into discussions about gravity and energy conservation. The technology aspect of STEAM is highlighted in the families' act of creating a solution for connecting the house models to the embankment. Families must think spatially about how many fixed pipe lengths they will need to place, where they will need to be placed, and how to use connectors and joints to guide their path appropriately. Finally, engineering concepts are reinforced as families test their designs with the marbles. They are able to see exactly where their design may have problems, allowing them to focus their efforts on which sections need to be refined.

Required Materials

During the prototype design process of this activity, a simple building system had to be defined to allow for robust spatial exploration by families when developing their solutions to the design challenge. Additionally, this system allows for multiple solutions to the same problem, which is an important goal for the overall delivery of the activity.

Figure 16: Stinky Sewers Building System

Since connectors add and remove dimension in certain places, this was taken into account when doing the math to determine the two main pipe lengths. Since the solution can be expressed as a ratio, there are infinitely many answers to this problem, but dimensions of 4” and 10” were eventually chosen due to the combination of two factors. The finished pipe structures needed to look substantial to the eye yet still be child-friendly enough to be held and manipulated by small hands. It is also for these reasons that a nominal diameter of 1.25” was chosen for the pipes and connectors.

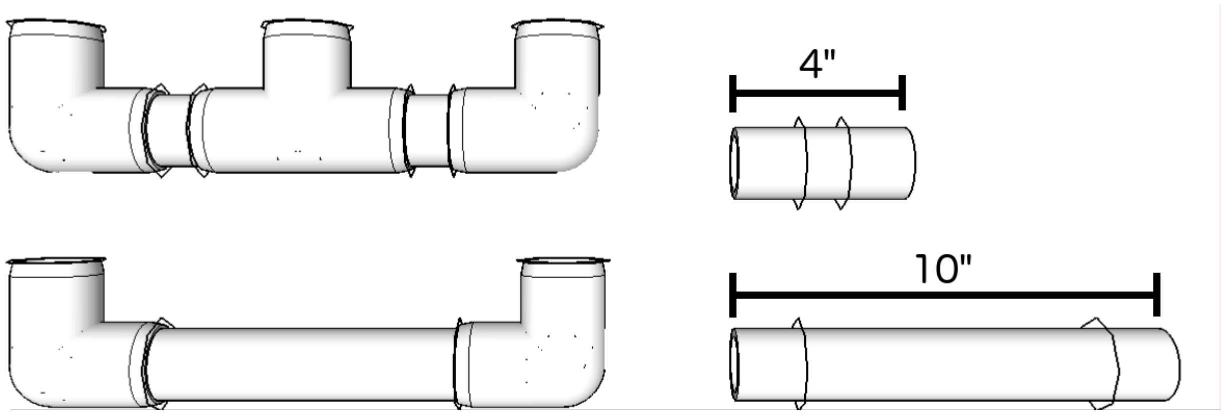


Figure 17: Schematic Showing Lengths and Intersection Zones

Like the other activities, a volunteer pack was created with the purpose of explaining to any member of museum staff how to run the activity with families. An additional goal associated with the packs was to explain any scientific concepts to the volunteers that may need to be taught to families. Not all volunteers will have a background in STEM, but this should not be considered a barrier to anyone who wishes to run the activity with families. As such, these explanations were made to be simple, avoid unexplained jargon, and build off of basic definitions that are common amongst people from all educational backgrounds and foci.

Group Size and Total Time

Through testing, we found that the common group sizes ranged between two and four people. Like the other activities, dwell time varied drastically, but the average tended towards fifteen minutes.

Detailed Summary of Activity

Upon beginning the activity, families are first presented with the story of the Thames Embankment followed by the challenge that was posed to engineers of the period: to connect the buildings of London to the newly built embankment. The hands-on portion of the activity begins with an introduction to the house models, and their features. These models are PVC structures with a small input to simulate waste inflow (marbles), and a larger output to adapt to the aforementioned 1.25” system. These house models are individual pieces, but can be shown as a set of connected buildings to add difficulty to the activity, should a greater challenge be desired.

The final primary component of the activity consists of a model of the Thames/Victoria Embankment. This model takes the form of a large pipe with a standard PVC joint secured to the top. The purpose of the Embankment model is to serve as the goal that families must reach. The joint is therefore placed to allow pipes to connect to some point on the model, illustrating the connection between the homes, pipe network, and embankment.

Figure 18: Full Activity Setup

Upon completion of their first solution, families can drop marbles down the holes built into the house models to see if they fall into the large embankment pipe. The opportunity to "win" is now presented. If their design connects the number of houses they chose to begin with and successfully directs marbles to the embankment, the design challenge has been overcome and children and parents alike can celebrate their victory. Should a marble get stuck at some point, this presents an opportunity for parents or the volunteer to explain why the design may have gotten stuck at that point, citing principles of gravity and energy conservation to show possible hints at a refined solution. Once the design is revised, families can repeat the marble-testing process until victory is achieved.

Testing and Recommendations

During the testing process for this activity, we considered three questions:

1. Is the act of building with the pipes and testing with the marbles smooth and intuitive?
2. Were the key learning outcomes satisfied?
3. Did volunteers obtain enough information to confidently carry out the activity on their own?

Volunteer Pack

The initial version of the pack was found to be historically informative, but light on scientific explanations, and too heavy on jargon. *Recommendations***:** Along with contributions from group members, project sponsors, and advisors, the pack was modified, and the finalized version can be found in Appendix Y. Additionally, we recommend that the museum explores different document organization methods when developing volunteer packs. This could minimize the need for large blocks of text in volunteer materials.

Pipe Fitting

With regard to the pipes, we found that due to obtaining pipes with the same nominal dimension from multiple sources, not all pipes fit with the joint pieces in the same way. A few pipes were found to fit slightly loose, while a few other pipes proved tough to couple and decouple. In practice, this did not significantly hurt the delivery of the activity as there were enough pipes that fit correctly to build large structures, but some groups did request more pipe. This required assistance from the activity facilitators to fit the pipes to any joint pieces. *Recommendation*: For the final version of this activity, a single source of pipe is preferred, and the fit should be pre-checked in the store before purchase of any material. That being said, the existing pipe can still be used. The pipes that fit too tightly can be modified to fit correctly by sanding off each pipe's small rounded flange that was created by the cutting tool. A final recommendation would be to add a few flexible tubes to the set. This would alleviate some of the design problems that arose when children decided to incorporate non-90-degree angle bends into their designs.


Figure 19: Flanges on Pipe Pieces

Marble Testing

The marble-testing portion of the activity was found to resonate extremely well with children in family groups. The marbles that were chosen for the activity were obtained from the Museum's gift shop, and were a perfect size to interoperate with families' PVC structures. *Recommendation***:** For the future, we recommend that some transparent sections of PVC pipe are added to the set in order to create the visual causality of the marble's progression through the network. While auditory feedback was enough for most groups, some families expressed a desire to be able to see the marble proceed through their creation.

Learning Outcomes

In all forms of pedagogy, verifying the successful transfer of learning outcomes is always a difficult undertaking. In this activity, this was done by asking directed questions towards families about certain scientific and historical concepts while carrying out the activity. This would always happen sometime after the tested concept was initially explained, plus some time for the concepts to be cemented through the hands-on activity. We found during testing that a plurality of children in family groups were able to retain all key learning outcomes, and through qualitative means, we found that children on average enjoyed the activity, citing either the process of creating the initial design, or playing with the marbles as their favorite parts of the activity.

One of the key outcomes that we wanted to see families understanding was that there is always more than one correct solution to a design problem. To see if this held true, various solutions of the activities were compared and contrasted after families were finished with their play through.

Figure 20: Comparison of Different Solutions

While some families chose to solve the problem with the least amount of pipes as possible, other families chose to add extra connectors, therefore requiring more pipes to complete the design. Those families who added more complexity were also able to see the need for expandability and future-proofing in their designs. Because of our findings, we can conclude that families did indeed create different solutions to the problem.

General Findings and Recommendations from Family Activities

While there were many findings that came from our activity testing, there is a subset of outcomes that spanned across all three activities. We believe that these common findings provide the basis for general recommendations that museum professionals can consider when building facilitated museum activities for families with a STEAM focus.

Trolley Placement

The physical location of the trolley in the Museum was one of the largest factors that influenced whether or not families would choose to interact with the trolley activity in the first place. Though the course of our testing, we were able to try all of our activities in three separate locations in the museum. Each location was able to give us useful information regarding how to place an activity trolley in any museum so that it has the best chance at reaching families.

Figure 21: Locations of Trolley Placement During Testing

One quality that an effective trolley placement must possess is an abundance of ambient light, or enough directional light to illuminate the activity trolley. If families cannot see where a trolley is located, or are not able to see what they are doing, families will not engage with the activity. The first image in Figure 21 had the most ambient light out of all of the trolley placements, and it invited wandering families to try the activities. It also allowed other families to find the trolley more easily.

A well-placed trolley activity will also keep in mind its position along the Museum's visitor journey, and relation to the other displays in the gallery. All activities that were run in the "No.1 Warehouse" gallery saw higher amounts of passerby traffic due to their close proximity to the many other interactives present in that section of the Museum. Additionally, No.1 Warehouse is the first gallery on the Museum's visitor journey. This meant that families were still in the initial exploratory phase of their journey, and not as eager to participate in facilitated activities. As a recommendation, trolley activities should be placed in less interactive sections of the museum to provide families with a break from text panels, and to keep children engaged.

Finally, trolley placement should also be influenced by the amounts of footfall present throughout a museum. Trolley activities placed in high foot-traffic areas (the middle image of Figure 21) saw the highest amounts of family engagements out of any of the locations that we tested in. As a recommendation, any form of traffic analysis of a museum would be beneficial in choosing locations to place activity trolleys.

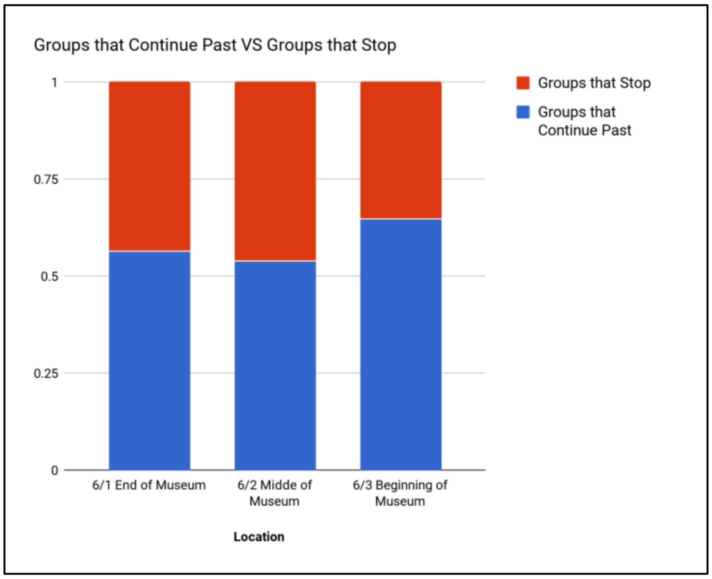


Figure 22: Graph of Groups the Participate vs Passersby

Scalability

Another common theme and important feature that all facilitated activities should have is the ability to scale for groups of varying sizes. In order to engage the most amount of people, both large and small family groups should be able to enjoy the activity. Additionally, multiple family groups should be able to collaborate together on the same activity, working together towards a common goal. This serves two purposes: It strengthens the impact of the learning outcomes, and it also keeps passing families from being deterred by an activity in progress. In the case of Stinky Sewers and Ship Shapes Through the Ages, additional families were reluctant to join into an ongoing activity due to either a lack of materials or space on the trolley. On the other hand, Ship Packing Puzzle was able to scale immensely, to the point of accommodating a group of 20 children, and even two families separated by a language barrier.

Overcoming a Language Barrier

The Museum of London Docklands is an international museum, seeing groups from across Europe and worldwide in the galleries daily. It is therefore imperative for museums to consider and accommodate for segments of its audience that are hearing impaired or unable to read. For this reason, we recommend that activities should be able to be completed without written explanations or verbal explanation by the facilitator, but we do believe that verbal queues provided by facilitators would provide families with the best experience. This can be achieved through color coding, pictorial clues, or multi-sensory experiences.

Connection to the Galleries

A robustly designed family activity must contain a strong link to a display in the galleries. This allows activity facilitators to connect families' experiences with what they are seeing in the museum, strengthening opportunities for family learning. Families enjoyed receiving directions to find a specific display relating to the galleries after the activity, along with answering questions about things they have already seen in the museum. Based on our observations, we recommend that family activities be placed appropriately either before or after the exhibit based on the nature of the activity and the exhibit.

Initial Explanations

No two family interactions are alike. Families have ranging dynamics and preferences, all choosing to interact with an activity in their own way. Activity facilitators should have the ability to adapt the delivery of their activity to families with these considerations in mind. If a family is beginning to get bored or confused, a facilitator should be able to recognize this and adapt the resource to best match the learning style of the family.

Developing the School Resource: Full STEAM Ahead!

In this section, we describe the steps taken to design, revise, and finalize a lesson plan for use by teachers of school groups visiting the MoL Docklands. First, we describe the methods detailing how the preliminary materials were compiled. This will look into considerations and design goals that were followed during the creation process. The methods in which our team carried out observations of school groups using the lesson plan will also be detailed. Finally, a set of recommendations for future development of the resource will be outlined along with general recommendations for museum professionals to consider when building teaching resources with a STEAM focus.

Methods for Development

As indicated in the background section, our team had conducted a preliminary review of the school curriculum for students in the London schooling system from ages seven to eleven, also known as Key Stage 2 (KS2). Based off the findings from Objective 1, the initial review of the KS2 curriculum, and a review of additional materials identified in interviews and museum visits, our team created a preliminary design for activities used to join the time in the classroom with the visit to the museum once in London. Additionally, our team worked with the MoL school group staff to gather more information about school groups and their visits to the museum. During this process, information used for family groups, which was still relevant, was referrenced to. When compiling the initial draft, several objectives were addressed. Namely, the desired learning outcomes from the MoL and teachers had to be identified. Furthermore, our team also had to choose which objects or exhibit items were being cover in the lesson plan. While choosing activities and materials to include in the pack, the findings from Objective 1 were taken into consideration. There had to be an underlying STEM concept in each area of the lesson plan's design in order to convey the majority intended learning outcomes. Along with representing these learning outcomes, the lesson plan had to also link to pertinent parts of the KS2 curriculum. In order to keep an engaging environment for a variety of students a mix of various content delivery methods were established. During this part of the design process, all of these factors, and more, were addressed in an iterative fashion in order to develop the final materials for the school groups.

Resource Purpose and Intended Use

To start the development of the school resource, we went through the activity list developed before and looked at ways to adapt activities to fit into an overall theme and to be large enough for a school group. When deciding on a theme, the different overarching ideas of the museum were taken into consideration. It had to be a theme that covered all galleries by having a relevant aspect. In the end, the theme that was utilized to tie the packet together was the river. Due to the docks location, and interaction with trade, the river is a connection with all of the exhibits throughout the museum.

The goal of the resource overall, was to create a tool for teachers to use during self-guided tours of the museum. The resource is for a teacher to run, leading activities and starting discussions, meaning students are not required to have their own packets. This allows for better engagement and focus among the students because there will be no additional materials for them to keep track of or get sidetracked by. By making a resource a total visit experience, a museum can greatly expand its capacity for school groups. If a teacher does not have to make their own resource, a trip is made significantly easier for them. The museum can use a resource such as the teacher pack in order to entice school groups to come to the museum. The easier the trip, and the more informative and interactive the experience is, the more likely the group is to visit.

When creating the resource, we took care to include a variety of different learning styles. In the packet were included stories, games, questions, and guided looking activities. These allow for an adaptive learning environment and keeps the visit varied and interesting. Each stop on the packet has a slightly different style from the last, engaging students who may not have learned from another activity. In the time allotted for the design of the packet, it was more practical to focus on a single floor. Due to this, our resource and visitor journey started at the beginning of the second floor. It started in the first gallery at the base of the stairs and then followed the regular visitor pathway through the remainder of the floor.

Methods for Testing

After implementing the findings from the previous task into the draft, our team was able to test with school group from the Thomas Gamuel Primary School. The group that came to the museum was around 60 students and six teachers. This however, was too large to go through as one group. The group was subsequently split into three groups of 20 students and two teachers each. Then, each member of our team chose one group to go with through the museum. Before starting the third floor both teachers were given a printed copy of the packet and given a brief explanation of our roles during their visit and the goals of the packets. We then followed our respective groups through the museum, trying to give as little additional information or interaction as possible. Our goal was to observe how the students and teachers interacted with our resource and the exhibits without any external prompting. If the teachers had questions or clarification, we gladly helped. If a student, on the other hand, had a question we directed them to their teachers.

Upon conclusion of the activities and their journey, each team member held a quick debrief in the form of an in-person interview with the teachers. Due to the groups having to get back to school by a certain time, the end of the trips were very rushed and minimal comments were made. The general feedback was positive and most modifications were due to direct observations. Unfortunately, due to scheduling, only one school was able to come in to test the resource. That the class was divided into three different groups, provided different dynamics that we were able to utilize in our final recommendation for school groups. This allowed for observations of different learning styles, class dynamics, and teacher dynamics. After the trial with the school, the resource was updated, incorporating the feedback from all three school groups and the museum learning staff. The final teaching aid will be presented to the MoL design team for them to expand and continue to modify the resources as they see fit as an appendix to this report (Appendix J).

Findings and Recommendations from School Resource

Testing the prototype resource with Thomas Gamuel Primary served to highlight what the resource did well, along with showing us areas for improvement. This section will note the key observations and further recommendations from this testing phase.

Student Engagement

Through testing, we observed that students enjoyed the process of learning from each other while completing the activities. This was best illustrated during the testing of the communication activity. Students would initially be confused as to how to solve the given problem, but as soon as one student figured out a method that worked, the entire class would follow suit, completing the challenge within seconds. One example of this happening was during a challenge where students were directed to non-verbally group by their favorite color. The group began with hand signals, trying to spell out the colors. Eventually one student, whose favorite color was red, walked into the center of the group and held up her red sweater. This immediately caused the rest of the students to follow the same method. Students who also liked red the most gathered near her, while other students began pointing to shoes or hair accessories to indicate other favorite colors.

Keeping students engaged with the resource for the entirety of the visit proved to be a challenge. This could be attributed to a multitude of factors. The purpose for the school's visit was intended to be a trip to celebrate their completion of the SATs exams. As a result, the school groups were very scattered and did not initially express a desire to focus on the museum. An additional factor that directed students' attentions away from the activity was the inclusion of a scavenger hunt from the teachers and chaperones. The scavenger hunt was treated like a contest: every successfully located object earned a student points. Whichever group earned the most points would win prizes in the form of candy. This caused students to focus intently on the scavenger hunt, with the hopes of winning the candy. Unfortunately, this left little time for each group to cover activities that our team designed.

Recommendation: Emphasize learning outcomes through activities as opposed to questions alone. While a small number of questions are okay, students and chaperones engaged more effectively with the activities. Additionally, do not incorporate worksheets into future versions, as the worksheet-based scavenger hunt divided the students' focus.

Unique Interpretation of Resources

Through the testing process, our team was impressed by how freely the students interpreted the activities while still arriving at the same intended learning outcomes. This was best illustrated during testing of the Frost Fairs activity. In this section of the resource, some students are directed to form arch shapes with their bodies while their classmates (representing water) can pass under and around them. By varying the number of arches, students can see why the decrease of arches in the New London Bridge caused the river to stop freezing in the winter. Although our team initially expected students to simply create arches with their arms, some students chose to form arches with their entire bodies, with their classmates crawling underneath. As expected, this caused a traffic jam amongst the students, who immediately recognized that they had become frozen water.

Recommendation: Make the intended outcomes clear, but the leave the process open to interpretation by students. This encourages a problem-solving mindset.

Positive Response to New Information

In alignment with our findings from previous objectives, it was enjoyable to see how well the school groups latched on to foreign concepts and new terminology. This showed through in multiple activities. In the rowing activity, students learned about the role of a coxswain on a rowboat, a term which was new to most of the group. Additionally, students responded positively to the section of the Blacksmith's Forge activity where the group learns about words that define the properties of metals like malleability and ductility. Students were also interested in researching further certain metalworking concepts like hardening, annealing, and normalization.

Recommendation: Include "Fun Facts" throughout future STEAM-based resources. These should be inspired by the intended learning outcomes for the activity. We also observed that humorous science facts were well-received by students, therefore we recommend inclusion of more of these in the future.

Aligning with Visitor Journey

The other primary challenge that made it difficult to test the full resource pack was the location of the museum where the activities began. Since the resource began on the second floor, and visitors begin their journey on the third, the school groups became accustomed to their initial pace of exploration. This made it difficult to regroup the students after completing their exploration of the third-floor galleries.

Recommendation: Begin all self-directed resources with some amount of information on the third floor. However, this recommendation is specific to only the Museum of London Docklands. In general, museums should always begin self-directed resources at the main entrance to a gallery. If the only way into a gallery is through the exit of another, the resource should begin elsewhere.

Wayfinding in the Museum

During interviews with teachers after the activities were completed, they indicated that it would be difficult to locate the resource's corresponding museum objects without our direction.

Recommendation: The packet should include a map with the object locations clearly marked. Additionally, the full collection of displays included in the resources could include physical numbering to help teachers identify them from a distance.

Clear Directions and Explanations

Teachers also identified that they were not prepared to give scientific explanations that day in the museum. This is due to a number of factors. First, the SATs exams currently only cover English and Mathematics. In the case of Thomas Gamuel Primary, the school had chosen to teach directly to the test and did not stress the Year 6 science curriculum. The intended use of the resource is for it to be read before coming to the museum. This coupled with constraints that kept teachers from reading the resource before their arrival also led to an unwillingness from teachers to lead the activities on their own like we intended.

Recommendation: Concise science communication is key to ensuring that pupils successfully obtain the desired learning outcomes. Avoid undefined terminology, and always derive explanations from common sense principles. This allows people from all backgrounds to be able to explain the concepts, and in turn, understand them.

Conclusion: Considerations for Museums Integrating STEAM

Our research and development process guided our group through a comprehensive study and confirmation of how families and schools learn in museums. We were able to expand our thinking, truly seeing the opportunities for all museums to contain connections to STEAM fields, not just science museums. During the process of synthesizing takeaway concepts from all three objectives of our research, there were many themes that remained present throughout each. From these common findings, we present a collection of general advice directed at museum professionals looking to integrate STEAM concepts into their museum.

Effective Thought Processes for Activity Design

Well-formed plans for an activity must be laid out long before an activity can be prototyped and tested. What is the story? What are the learning outcomes? How does this connect to the galleries? How does this connect to STEAM? As a group, we initially found difficulty in creating activity plans that were diverse and robust. In other words, we were not able to come up with a large amount of activities, and their STEAM connections were not as strong. After reflection, we identified that this was due to our tendency to look for STEAM outcomes before considering the backstory of an object. During our second pass of the Museum, we stopped at every object and display, considered the backstories, and used the formal definitions of STEAM to discover new connections that we missed earlier. We would highly recommend this methodology for any museum professional looking to develop any sort of museum activity - for families and school groups alike. We additionally recommend that museum professionals keep touring their galleries on a regular basis, along with maintaining a collection of possible activities for each display.

Advantages of Trolley Activities

Facilitated family activities have been an effectively proven scheme in museums for decades. Even though the “trolley” method has been around for considerably less time, we were able to see the solutions and opportunities that this method of activity delivery provides. Through our background research and museum visits, we were able to see that trolley-based activities have the ability to flexibly add opportunities for engagement in a museum. Thanks to their inherent mobility, museum professionals can adjust where and what activities are delivered at any time. This allows learning professionals to more easily keep up with the fast-evolving environment created by curators. Our testing was able to further confirm these observations, along with showing us the ease of setup and transport firsthand. From this research and testing, we would recommend that museums adopt trolleys more widely in their galleries.

Innovation in the Museum Community

One common theme that we gathered from our time conducting research was the growing sense that we were not alone in our efforts. Through our initial background research, we were able to examine a subset of a large and active community of museum researchers. This carried through while in London. Even during unscheduled visits, staff from other museums were always welcoming toward our team, and were excited to show us delivery methods that worked well in their galleries. They were also inquisitive about our project, and were excited to hear about our test results. From these findings, we concluded that by nature, the majority of the museum community is interested in what other parties are developing and perfecting. We were intrigued by the museum community’s propensity to freely share ideas and embraced this methodology through the course of our project. From this, we recommend that future museum professionals adapt our ideas for their own work, keeping with the community's tendency to freely share.

Final Thoughts

To quote Frazer Swift, head of learning at the Museum of London, "people come to museums to be inspired." This quote truly set the tone for the majority of the project, and we therefore set out to do exactly that. We were able to allow the Museum of London Docklands' galleries to inspire wonder in ourselves. We then used the branches of STEAM to find connections and create learning outcomes that inspired families to wonder as well.

Bibliography

Ahmad, S., Abbas, M., Yusof, W., & Taib, M. (2014, February 26). Adapting Museum Visitors as Participants Benefits their Learning Experience? Journal of Museum Education.

Association of School and College Leaders. (2015, May 5). Education Funding. Policy Paper.

Barnes, Kassandra; Marateo, Raymond C.; and Ferris, S. Pixy (2007) "Teaching and Learning with the Net Generation," Innovate: Journal of Online Education: Vol. 3: Iss. 4, Article 1.

BCLM. (2017). STEM at the Museum. Retrieved June 21, 2017, from https://www.bclm.co.uk/learning/stem-at-the-museum/460.htm

BCLM. (2017). Visiting us. Retrieved June 21, 2017, from https://www.bclm.co.uk/visiting.htm

Braund, Martin, & Reiss, Michael. "Towards A More Authentic Science Curriculum: The Contribution Of Out-Of-School Learning". *International Journal of Science Education* 28.12 (2006): 1373-1388. Web. 27 Apr. 2017.

De Brito, P. (2017, March 31). Telepresence interview.

Dierking, Falk, J. H., L. D., & Foutz, S. (2007). *In principle, in Practice: Museums as Learning Institutions*. Lanham, MD: AltaMira Press.

Docklands, M. O. (2017). Families at the Museum of London. Retrieved April 10, 2017, from https://www.museumoflondon.org.uk/families/visit-museum-london-docklands

Docklands, M. O. (2017). Schools at the Museum of London. Retrieved April 10, 2017, from https://www.museumoflondon.org.uk/schools/

Docklands, Museum of London. (2013). Capital Engineers. Unpublished Lesson Plan.

Essex. (2013). Chemical Analysis Project: “What did Doo’s Do?". Retrieved June 21, 2017, from https://www.bclm.co.uk/learning/chemical-analysis-project-what-did-doos-do/463.htm

Exhibitions and Displays: Museum of London. (2017) Retrieved from https://www.museumoflondon.org.uk/museum-london/whats-on/exhibitions

Exhibitions and Displays: Museum of London Docklands. (2017) Retrieved from https://www.museumoflondon.org.uk/museum-london-docklands/whats-on/exhibitions

Falk, J. H., & Dierking, L. D. (2000). Learning from museums: Visitor experiences and the making of meaning. Walnut Creek, CA: AltaMira Press.

Forrest, R. (2013). Visitor Statistics: Young Adults and Museums. Retrieved April 12, 2017, from http://reganforrest.com/category/statistics/visitor-statistics/

Fricke, A., & Taylor, A. (n.d.). *Mildred Lane Kemper Art Museum STE(A)M Tour: Grades K-12* [A guide for an exploration of the ways science, technology, engineering, and math are related to art.].

Griffin, J. (1998). School-museum integrated learning experiences in science: A learning journey. Unpublished PhD dissertation, University of Technology, Sydney, Australia.

Inspiring A Passion For London, Strategic Plan 2013-2018. (2013). (PDF), Retrieved from http://www.museumoflondon.org.uk/application/files/1414/5763/4159/strategic-plan-2013-18.pdf

Luke, J. J., Bronnenkant, K., & Dierking, L. (2003). Parent Partners in School Science: Year 2 final report. Unpublished evaluation report. Annapolis, MD: Institute for Learning Innovation.

Moussouri, T. (2002). A Context for the Development of Learning Outcomes in Museums, Libraries and Archives. The Council for Museums, Archives, and Libraries.

Mudlarks. (2017). Retrieved from https://www.museumoflondon.org.uk/museum-london-docklands/permanent-galleries/mudlarks-childrens-gallery

Parents and Motivations: An (Unexpected) Sneak Peek. (2016). Retrieved April 12, 2017, from http://www.wilkeningconsulting.com/datamuseum/parentsmotivationspeek

Permanent galleries at the Museum of London. (2017) Retrieved from https://www.museumoflondon.org.uk/museum-london/permanent-galleries

Permanent galleries at the Museum of London Docklands. (2017) Retrieved from https://www.museumoflondon.org.uk/museum-london-docklands/permanent-galleries

Randol, S. (2004). Looking for inquiry: Developing an instrument to assess inquiry at museum exhibits. Proceedings from annual meeting of American Educational Research Association (pp. 1– 22). San Diego, California.

Sibieta, L. (2015, 26 March). Schools Spending. Policy paper, Institute for Fiscal Studies.

Storksdieck, M., Falk, J. H., & Witgert, N. (2006, April 3– 6). Why they came and how they benefited: Results of 52 in-depth interviews conducted 18 months after a science center visit. Paper presented at the NARST 2006 annual meeting, San Francisco, CA.

Tal, R., Bamberger, Y. and Morag, O. (2005), Guided school visits to natural history museums in Israel: Teachers' roles. Sci. Ed., 89: 920–935. doi:10.1002/sce.20070

Wu, K. (2011). What do families with children need from a museum? Cultural Policy, Critics and Management Research. Retrieved April 10, 2017, from: https://culturalpolicyjournal.wordpress.com/past-issues/issue-no-2/do-families-need-a-museum/

Appendices

Appendix A: Frazer Swift Interview. Preamble, questions, and notes

WPI / Museum of London Interviews - Frazer Swift

Attendees: Ian Gelman, Tommy Maloney, Krysta Murdy, Frazer Swift
9/07/17

Preamble: We are students from Worcester Polytechnic Institute, a university in the United States. We are conducting research with the Museum of London Docklands to design an activity trolley for families to promote STEM learning. The trolley will feature an assortment of activities inspired by objects and exhibits from the Museum's collection. Would you be willing to answer a few questions regarding your experiences and knowledge of family learning at your institution? Would you mind if we quote you by name in our report? We will give you an opportunity to review any quotations before publication. If you prefer we can anonymize your responses."

- Identify Fraser's Role in Organization. More than just day to day activities, ask what long term things Frazer is working on.
- Based off of the exhibits and activities in the museum, what features do you feel best engage families? What are your most popular exhibits/activities with families? Give some insight as to why that may be?
- Family vs School groups
- What aspects of activities do you think will apply to the broadest range of people, different ages, learning styles, genders?
- What role do you think science education has in a social history museum?
- How do you see museums like the MoL making changes in their social and history education for KS1-2, now that the curriculum has changed?
- What opportunities does the MoL Docklands have in developing links to STEM now that the KS1-2 history program is no longer a primary focus? What are Docklands' selling points in this regard? What qualities does this museum posses that other museums don't?

Meeting Minutes:

Families vs. Schools

**more preparation = more receptive since the information is at the forefront of the mind

**different social dynamics

School

- ➢ Specific focus
- ➢ Already briefed
- ➢ More receptive because they're already thinking about the material
- ➢ Assume unprepared
- ➢ Clear curriculum links
- ➢ More students working with students

Families

- ➢ Less structured

Science in Social History

curriculum dictated

- ➢ Pick topic and go beyond local
- ➢ Varying definitions of local: all London, borough, street
- ➢ Teachers come on history visit but tie in STEM
- ➢ Holistic approach/fusion of topics
- ➢ Skills development
    - ○ Fusion
        - ■ Valuing creativity

Men vs. Women

- ➢ STEM is male dominated
- ➢ Avoid stereotypes by ***assuming*** what each is interested in
- ➢ Younger children have very similar interests
    - ○ Society manipulated people to conforming to gender stereotypes
- ➢ Challenge stereotypes by representing genders as opposite as what you would expect
    - ○ WWII: women took on male roles

- Trade is male dominated

<u>Long Term Projects</u>

Changes he’d like to see

- *<u>In general</u>:* much more interactive and family/children oriented
- Currently rely heavily on events and workshops to bring the materials to life
    - Because the exhibits themselves are text heavy and not very interactive
- Facilitate interactivity!!
    - Family intervention project
- More *<u>creative</u>* in engaging families
- History museums are meant to invoke how we think about the future and how we feel about it. What can we learn from this history?
- Learn from science-centered model
    - How is history relevant to the present?
- Digital technology to engage families
    - Make use of family mobiles to guide them and etc.
        - People don’t want more technology in the exhibits
            - There is a lot of digital there anyways
- “They come to museums because they are inspiring places”
- People like a person to make connections for them
    - Provide this through digital means
- Digital activities: games, talking points, puzzles for them to take with them

<u>Noteworthy Things for Our Project</u>

- Capture opportunity for digital
- Explore collections and exhibits
- Add value
- Point out easily missed details
- Health and safety things
    - Lost/stolen
    - Sharp

- Easily swallowed

➢ **Go beyond the obvious**

➢ Push outside comfort zone

➢ New twist on traditional methods

➢ Use water

- Closed in, slip ship in through slot?

➢ Identify Spaces in and next to the gallery where you can be more creative

Appendix B: Activity Proposals

Introduction

As part of the research undertaken by our team, we have compiled a set of 12 activities based on displays and current gallery exhibits. Each activity proposal consists of an overview detailing what families would interact with on the trolley, and how the activity could be facilitated. Intended learning outcomes are also specified in each proposal, with the goal of providing key takeaway points for families after experiencing each activity. Finally, the ways in which each activity connects to the different areas of STEAM are overviewed.

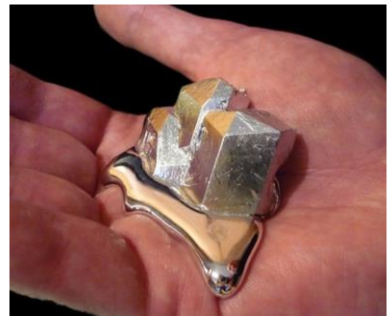
Aging and Preservation

Aging and preservation is an important topic to explore in museums. Without the efforts museums put towards preservation, many artifacts would no longer be intact or, in extreme cases, exist. This activity explores the effects of aging on different materials and the ways museums preserve artifacts and prevent further damage. Families are presented with different materials--cloth, ceramic, glass, metal (coins)--and asked to think about how time would affect each of them and what factors would change these effects. It is important to encourage the families to think about the possible effects of the River Thames, of different soils, and of different environments. This kind of analytical thinking is called hypothesizing. By regarding the materials in this way and by observing the objects in the museum, families are practicing science. At this point, the volunteer should have given the families facts, questions, and explanations from a volunteer pack that allow the families to understand why different types of aging occur, why certain materials are not frequently discovered, and why museums are important to the preservation of artifacts. Have families discuss and design exhibits that could preserve artifacts of different materials, and by doing so they will be gaining experience in technology. The families will then be challenged to find evidence of aging in the exhibits and some of the measures taken by the museum to preserve the artifacts. A good example of aging can be found on the second floor in the Sugar and Slavery gallery. There is an exhibit in this gallery that contains a jar full of shredded leather, this leather was a whip until it touched the air and fell apart. Near this, there are some documents yellowed with age. It would be interesting to have families think about what was used as paper then versus what is used now and how they might age differently. With this activity, families should take away a better understanding of artifact preservation and the challenges that museums face when designing exhibits.

Blacksmith's Forge

Overview

In this activity, families will pay a visit to the dock blacksmith's forge. During their time spent there, they will learn about the properties of different kinds of metals, and the tools that helped the dockworkers through their backbreaking work days. The activity will incorporate elements of object handling, showing families the differences between metals like copper, aluminum, and iron by presenting samples of copper wire, aluminum flat bar, and iron flat bar. Questions can be asked by parents and volunteers regarding their differences in weight, flexibility, apparent temperature while handling, Objects like magnets and coin cell batteries with LEDs can also be laid out on the trolley to explore the chemical properties of these metals along with their physical ones.



Families could also experiment with some exotic materials, namely gallium and nitinol. Gallium is a non-toxic metal that has a melting temperature of 30 degrees Celsius. Giving families the opportunity to safely handle soft or molten metal will show how metals change phase, and will also show how blacksmiths worked hard metals into many different shapes. Nitinol is a shape memory alloy that can be deformed at room temperature, and then can recall its original position when placed in warm water. Regarding procurement, gallium is sold in many online and brick-and-mortar specialty toy shops (including amazon.com) in quantities of 50 grams each. Nitinol is sold in wire form at similar shops as well.

The final component of this activity challenges families to think of an everyday household problem that they experience, and then create a tool using bunched-up aluminum foil that could help them solve the problem. After their designs are completed, volunteers and parents can ask questions about what materials should be used to make the actual tool and why. This connects back to the family's initial exploration of the different properties of metals. Additionally, families can role-play dockworkers and blacksmiths - describing problems, and then solving them with the construction of a tool.

Learning Outcomes

After completing this activity, families will see how all materials can exist in multiple phases, and how people used this to their advantage to help solve problems. Families will also be able to take home a myriad of facts regarding the properties of metals, and certain definitions like ductility, malleability, conductivity, and ferromagnetism. Finally, families can have conversations during the exotic material demonstrations, sparking further research after the museum visit.

STEAM Connections

This activity has a strong science component during the initial phases of the activity. Families will make observations about their environment in order to learn more about it. Families are also able to observe the behaviors of exotic materials, and form hypotheses about how these properties manifest themselves. In the final portion of the activity, the focus shifts mainly towards the technology aspect of STEAM. This portion challenges families to devise solutions to problems that they define themselves or get provided by volunteers.

Communication

Overview

This activity dives into the history and development of communication around the docks and out at sea. Families are given the opportunity to try out a number of communication methods from across the ages. Methods can include flags, Morse code, radios (walkie talkie), sign language, and whistles. After learning the basics of each method, both how to communicate in that style or how the science of it works, the goal is to say their name or another simple phrase using each technique. If with a larger group they can turn it into a game of telephone, passing the message from person to person and the last person reveals what they think the message was and the groups sees how much it may have changed. At this it would be a good time to talk about pros and cons of each method. For example, if a whistle or tap of Morse code is lost the words can be lost but they can be listened to and written down at the same time. However, flags or sign language require line of sight and a close enough proximity to see. This brings to light the importance of a universal communication system so that different groups can communicate. At the same time it shows the need for advancements in communication methods. Certain techniques cannot transmit certain aspects or nuances of statements. The families can then talk about development of communication and what it methods have come to be, such as video chats. Finally, it can be asked what do they think the future of communication is and what direction it will take.

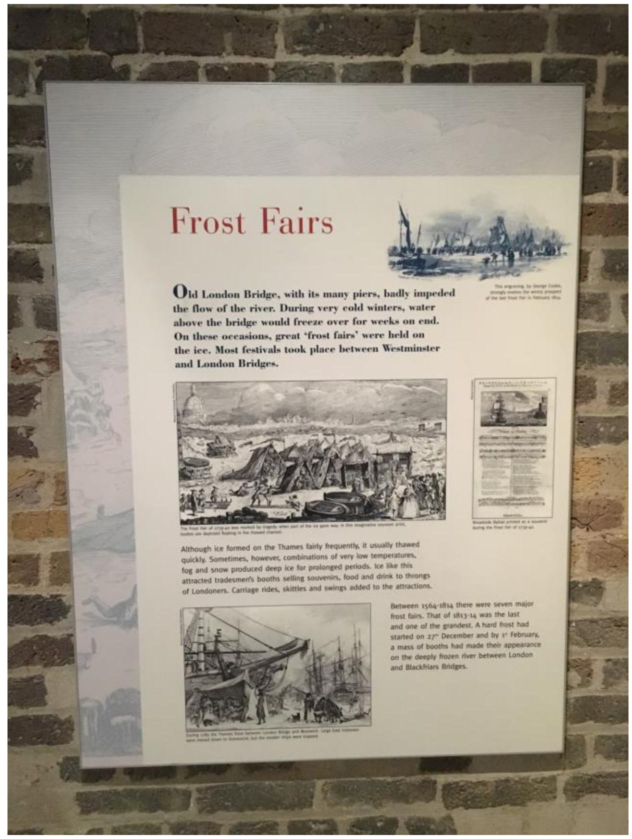
Learning Outcomes

The goal of this activity is to explore the need for communication systems and how there are always ways to improve them. These needs for improvement are what drive the engineering process and create new inventions and improvement in the world in every field. What other fields have a clear progression of development due to technological advances and improvements? What does a current version of something in that field do better than one when the field was first invented?

STEAM Connections

This activity has strong science and engineering components. Families will learn about the benefits and detriments of the different communication methods and discuss which may be better in different circumstances.

Frost Fairs



This activity is meant to give families a strong visual to help explain why the River Thames used to freeze in the winter and an opportunity to design their own bridges. It is important to present families with open-ended questions that provoke conversation and deeper thought. Volunteers should have families thinking about why some bodies of water freeze while others do not, why a frozen river could be beneficial and why it could be harmful, why bridges are important, how bridges affect water flow, etc. There will be a device made out of wood and plastic that is full of rice and pegs that can be pushed up to act as arches. This will be a size that will allow children to pick it up and tilt it to watch the rice move around the pegs. The volunteer can prompt the families to use this device to determine why the New London Bridge does not affect the river in the same way as the Old London Bridge. By observing the rice through the pegs and hypothesizing about why the bridges affect water flow, the families are practicing science and should be informed of this to reinforce that science is very achievable. Families will be encouraged to use the pegs to try out different bridges and to think about what each might look like and if it would be structurally sound.

Learning Outcomes

After experimenting with different designs, families will have the opportunity to challenge their artistic abilities by drawing out with a pencil and paper what their bridges might look like. Families should take away a general understanding of how bridges and water interact and how water flow affects the ability for water to freeze.

STEAM Connections

By designing bridges to do certain tasks and by using the knowledge of how the rice interacts with prior designs to develop better bridges, families are practicing both engineering and technology.

Hats

Overview

All throughout history people have worn things on their heads. Sometimes just for decoration and other times they have had an extra practical purpose. The purpose of this activity is to explore the uses of specialized hats in different jobs. Looking at the different materials hats were made of for fashion or utility is a very in depth area. Materials for hats made for fashion are carefully examined based on rarity and quality. The rarer the material and the higher the quality material, the more expensive these hats would be. Hats were a large part of high society and held a place as a status symbol. The nicer and the more expensive a hat the more important the person often was. For those who did not use the hats as status symbols, they used specialized hats for their job. For example, fish porters had hats made of leather and wood with large brims. The wood held up the weight of the containers so their heads would not hurt as much. The leather and large brim would keep the liquids from the fish from dripping down on their faces or soaking into the wood and rotting the hats. Modern hard hats and helmets protect people's heads from impacts and lots of research go into improving them every year. After going through different materials and their uses the families have the opportunity to design a hat of their own either for a specific job or for fashion taking into consideration materials and uses for the hat. Why did they use the certain material they did and how did that fulfill needs for their job? They can either draw it all out or fold paper to make their own hats.

Learning Outcomes

This will have families learning about the process behind planning out and designing different items. They will look at what sort of considerations must be made when choosing materials and how to design to a specific challenge. These are important aspects of the engineering design process that families should learn about through this activity.

Material Analysis

Overview

Families play the roles of port tally clerks and testers, ensuring that all goods coming into the docks are properly labeled and are not counterfeit. Family members can weigh different sacks and crates, along with measuring them or using a magnet to figure out which one is a bag of sugar or sand, aluminum or iron filings. Clerks will receive a list of all objects that need to be checked, and will work with testers to verify that everything is labeled correctly. Family members can compete with each other to check off the most things in a certain time frame.

An additional consideration for this activity would be to have a space with a microscope set up, containing slides of sugar and sand samples. Families would be able to examine the samples, and see the visible differences between the two materials. Due to the large size of sugar and sand granules, an actual microscope is optional for this portion. A tablet or cell phone fitted with a clip-on macro lens will also produce the desired effect. These lenses commonly retail for less than five pounds from electronics and hobby shops. Volunteers can ask families what they think dockworkers in the future might do to verify the authenticity of materials, and compare it to methods employed in the past.

Before containerization was introduced, theft in the docks was a known issue. Steps were taken to prevent this from happening, like preventing dockworkers from wearing clothes with pockets. Despite this, dock masters needed to cooperate with tally clerks to identify when goods had been stolen, and to stop future thefts. Families can role-play this situation out for themselves. How would they figure out if goods were stolen from the warehouse?

Learning Outcomes

Intended learning outcomes from this activity center around the principles of teamwork and the scientific method. Teamwork skills are strengthened through the interactions between testers and clerks. Principles of the scientific method are also shown through the process of challenging families to come up with hypotheses for what a bag may contain, and then having them test their claims through measurement and analysis. Scientific concepts like mass and solubility can also be explained when describing the chemical differences between sugar and salt. The intended goal is to inspire children and families to use what they learned about the scientific method to stoke their curiosities, and to help solve problems in their everyday lives.

STEAM Connections

Families will grasp scientific concepts through making observations and measurements. They will be able to become more comfortable using the scientific method to prove or disprove hypotheses that they make. Families will also get to experience the many different technologies that were used to do the same task, with the opportunity given to ponder on what the future may hold.

Navigation

Overview

Before the invention of GPS and other navigation methods, sailors had to figure out their location by using the positions of stars and the sun. This was possible because the stars are always in a predictable location and order depending on time of day and time of year. These observations and calculations were complicated and took a lot of math and memorization to determine locations. This meant navigators were highly trained and much more valuable than an everyday sailor. A ship could not set sail without a navigator or two on board or else they would be unable to make it to their destination.

In this activity the goal is to figure out their location using different methods through the ages. After learning about the role a navigator would have on the ship the guests would be told about the different types of tools used for tracking their location such as a sextant, astrolabe, and compass. Each tool would be described in their use and the math behind it. There would be replicas or artifact versions of these to test and look at. Next, they would be given a set of picture of what the stars looked like and measurements that would have been taken from that location. From this information they would have to find their location in the world on a map. After going through the methods from the past, the families will be invited to look at their phones and see their mapping applications. With satellites and cellular towers across the planet we can now track objects and find our location down to the meter. How can cell towers be used to triangulate the position of someone? What sort of systems may be used in the future?

Learning Outcomes

After this activity, families can see how navigation was approached throughout the ages. The limitations of ancient times sometimes meant they could only sail near land and only in previously charted waters. This is why explorers were so important in order to discover new locations and routes that would be safe for travel. The concept of required accuracy should also be discussed. For a ship traveling across the sea their accuracy could be less, as long as they were within a certain zone they would reach their destination. However, in today's world accuracy of tracking must be much more accurate. What situations would require precise mapping or tracking?

STEAM Connections

This activity is intended to teach about the science of the stars and how they can be used to find our location on Earth. These observations of the stars allow for navigation due to their predictability. This activity also discussed the different technologies and tools used through history and what is used now. By examining the development of tools through time, taking aspects that work from old versions and adding features based off new knowledge, they can think about the development of new technology and look to see how technology of the future may look. The math in this activity is a very important theme. Most of navigation comes down to math. In the past it was done by hand or in one's head in order to figure out where the ship was but now computers do all the math for us, taking in distances to multiple known locations and finding the intersection point of these distances.

PLUTO Pipelines

Overview

PLUTO Pipelines is a map-based activity centered around the construction of the aforementioned pipelines during World-War II. These pipelines helped to establish a supply of petrol from England to France. The pipes were designed to be strong, yet flexible. This allowed the pipe-layers to avoid German patrols and natural obstacles while still making forward progress. Families will be presented the challenge of connecting points across the English Channel using magnets placed onto a map, while simultaneously routing their pipes around obstacles on the map. Families must take care, because there will be a limited number of magnets available to solve the puzzle. After the activity has been completed, families can be directed towards the sample of PLUTO pipe in the "Docklands at War" gallery.

During the activity, families can talk about why petrol is important in today's society, and how it was depended upon even more during wartime. Alternative energy sources in the present can also be discussed. Families can role-play what they would feel like to be on the boat laying the pipeline. What problems would arise? How would they solve them?

Learning Outcomes

Families will learn about the purpose of the PLUTO pipelines, and how they assisted the Allied forces in World War II. This also activity largely focuses on developing families' spatial thinking skills.

STEAM Connections

Technology concepts are addressed when given the defined problem of connecting several points between England and France with pipe. Mathematics skills are honed in this activity as well, thanks to the map's ability to turn pipe-laying into an abstract system.

Sails

Overview

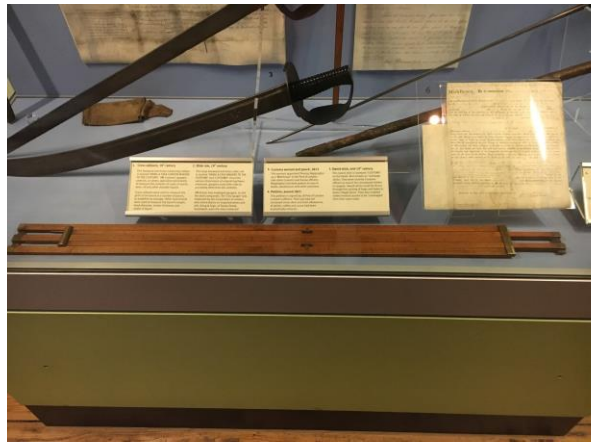
In this activity families will look at the different styles, shapes, and materials of sails. Discussion about the different types of sails and their uses will be addressed. Comparing sails such as boomless sailboat sails and boomed fixed sails. Talking about their uses in different scenarios and why each was used in the way or specific ship it was. What types of sails were best for certain situations. What were advantages and disadvantages of each type of sail. Also, the science behind sails and how they redirect the wind allowing ships to sail into the wind and faster than the wind by use of perceived wind and actual wind.

After, the families will be able to test out different types and styles of sails in a test rig with a fan. Before testing, they will predict which type of sail produces the most force at each wind angle. The force produced by the sails will be measured through a force gauge attached to the top of the model mast. This will be stationary as the wind source moves around it. This will demonstrate that even when the wind it at an angle the sail produces a force along the axis of the ship to propel it forwards.

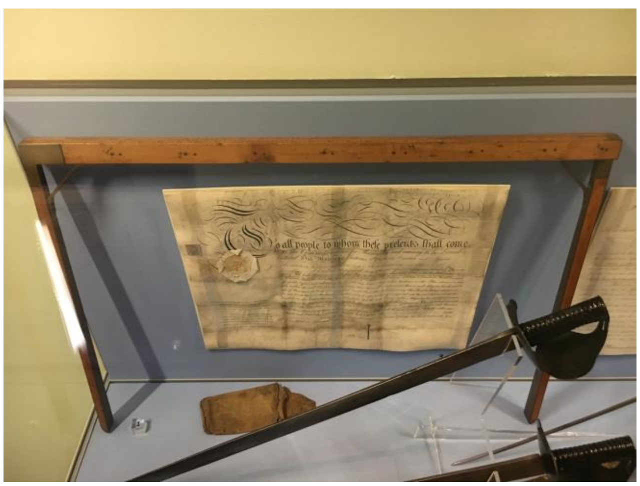
Learning Outcomes

Through this activities families should gain a basic knowledge of how sails interact with the wind and how they redirect the air to exert force forwards on the ship. As the force is directed into the sails and through the mast into the ship, the reaction generated is opposite and propels the ship forward. This understanding will come through not only the explanations from the person running the activity but also their observations of the wind interacting with the sail in the sail testing rig. Using their existing knowledge, gained from the activity, of how certain sails interact with air at certain angles, based off requirements for the sailing style or ship type, they will use their critical thinking and analysis to come up with a design for the given situation in the activity. These are steps and considerations that designers and engineers must make when designing sails for each ship they work on. While using their critical thinking for a starting point it is clear that prototyping, testing, and revising are all key elements of the design process and are necessary when making anything new.

Slide Rules and Calipers



In this activity, families are guided through the steps of determining the tax on the goods in a barrel. There will be a jug of something, possibly candy, out for families to see. Upon investigating this jug, families will be asked to guess how many pieces of candy are in the jug. It is important to explain to families that by making a guess based on what they see, they are forming a hypothesis and thus are practicing science. A simplified explanation of taxation will be given to the children, and they are encouraged to guess what the tax might be on the candy in the jar. They are then presented with a caliper and a slide rule, the use of which is explained and demonstrated. A caliper is used to determine the diameter of a barrel, and a slide rule is used to determine its volume. With these tools, the volume of the barrel can be calculated, and given the density of a piece of candy, the number of candies can be determined in just a few simple steps. Families are challenged to use these tools and a sheet with all the necessary information to determine how many pieces are actually in the jar. The volunteer will give the families some time to contemplate how to complete this task and then will talk the families through the process. Once the families calculate the number of pieces, they compare it to their guess, and if they are with a certain proximity to the calculated value, they get to take a piece of candy. Families are then given the chance to update their tax guess before the volunteer discloses the actual value. The volunteer will then be able to present the families with a sheet detailing the average size of the barrels and the typical tax for the different goods imported at the docks. With this activity, families should take away a basic knowledge of volume and a general understanding of taxation.



Learning Outcomes

With this activity, families should take away a basic knowledge of volume and a general understanding of taxation.

Swords

Overview

This activity is exploring the different types of swords used on ships or experienced by travelers while traveling the globe. They will talk about the different uses for each sword such as cutting through metal armor, thrusting, and close quarters fighting on a ship. The activity will first look at the different people on ships and at the dicks that would have swords and what types they would have. Next, using model sword pieces, such as handles, blades, and cross pieces the guests have the opportunity to make their own swords. First they will be prompted to build swords for certain roles. After, they make their own swords of whatever design they want with the pieces provided or just drawn on paper however they choose. Then they will look at the advantages and disadvantages of the sword they made or designed.

During this, as a reach goal, they can discuss the types of metals and methods that went into making swords. This section would talk about the techniques different societies had for making their swords, such as cast bronze swords, uniform metal swords, or multi metal swords such as the high carbon and low carbon combination in a Japanese katana. After talking about the different techniques used in different societies methods such as annealing, tempering, and normalizing the metal can be discussed. Their benefits and uses in the forging process can be talked about on a molecular level covering the crystallization in the metal and why it would act differently after each process.

Learning Outcomes

Families will learn about the uses of different types of metals and the ways of working them. Metallurgy is a very extensive field and it would be impossible to have a full understanding of the craft after one activity. However, the basics of the methods and impacts on the metal should be transmitted. These ideas can spark interests and further research into the topic for families who are curious about more of the processes.

STEAM Connections

This activity looks very heavily at the use of science in metallurgy to solve problems and create swords for use in different situations. Each sword will react or work best in its designed situation. An executioner's sword will cut through flesh where a great sword is more designed for armor. As technology changed, different methods of making swords arose, based off new alloys or materials. During each era, swordsmiths were considered artists. They always wanted their work to look beautiful as well as functional. The families can continue this tradition when designing their own swords, making them look however they imagine it.

Tool Analysis

Overview

This activity is geared towards the younger age ranges. In it the visitors will examine the efficiency and practicality of different tools and materials while transporting certain goods. They will test different samples of packing materials used in the docks to determine why certain goods were transported in certain ways. Some examples include discussing why sugar is stored in sacks and not in crates. This can be shown by having a model crate which a light can shine through. All the holes where the light penetrates would allow the sugar to escape. When looking at cloth bags, however, there is a large amount of really small holes. Why would this be a better method? Humidity, moisture in the surrounding air, causes the sugar to clump up. This means it is unable to pass through the small holes of the cloth but still would be able to pass through the larger holes in the crates.

After evaluating why certain packaging materials were used for each good, families will have the opportunity to examine the different types of tools and speculate about which material they would be used on and why they would not use them on others. For example, single hook handles can grab onto a wooden crate with ease and bit into the wood. However, that same tool, if used on a bag of sugar, would simply tear it in half. When looking through the different package models they would test out miniature tools on samples of materials. These could be replicated in ways such as Velcro hooks on the burlap, blunted calipers to grab into the crates, and small barrel loop to grab a barrel.

Along with grabbing the objects, the visitors will look at simple machines and other devices used to unload the ships and move the goods around the warehouse easier. How do the simple machines come together in order to create more complex machines in order to lower the amount of labor while unloading. (ex, cranes) Through this conversations about simple machines can be brought forwards, discussing what simple machines were used in the warehouse, such as pulleys, levers, inclined planes (slanted floor), and wheel and axles. These objects can tie back into their own personal lives. What simple machines do you use every day?

While working through the activities, volunteers can tell stories about how dock workers were day laborers, meaning work and pay was not guaranteed. This allows guests to step into the shoes of dock workers and gain an understanding and empathy for what they did every day.

Learning Outcomes

Through this activity, families will learn, through observation, the importance of practical packaging and handling of goods. The realization that by using the correct methods and tools it makes the process much easier. Despite packaging seeming to just be natural, there is a lot of thought that goes into the process. What sort of packaging may they take for granted in their everyday lives? Another thing that they may take for granted in their lives is the number of simple machines they use every day and how it makes their lives easier. The use of simple machines in combinations to form complex machines make up many items in the world around us. How do they think they can use new simple machines to make their lives easier?

Appendix C: Volunteer packs from the Royal Institution

Demonstration name	DNA Keyrings
Equipment checklist	· String · Beads (in cups) · Scissors · Keyrings · Print outs: o Instructions o Sequence chooser o Pairing rules o Sequence information
What to do/instructions	The aim of this activity is for the children to make a keyring with a DNA sequence of their choice and, whilst doing so, learnt the process of how DNA is replicated during mitosis. Participants can follow the printed instruction sheets, and whilst they are making their keyrings, you can talk to them about the science below.

What's the science behind this?	The four coloured beads being used to make these keyrings represent the four bases which make up the DNA of all life on earth: · Adenine - A · Thymine - T · Cytosine - C · Guanine - G No matter which section of DNA we look at, and from which organism it comes from, it will always be made from this same 4 bases. All DNA of all life on earth has DNA made from the same basic set of chemicals! Of these bases, A always pairs with T, and C always pairs with G. This means that, in the double helix of DNA one strand is the inverse copy of the other. This is very important when it comes to cells replicating. When Cells make copies of each other, the DNA double helix unzips to become two strands. Free bases (or beads) then attach to these two single strands, creating two new double helixes. *This is the same process you used to make your keyring!* You make one strand, and then looked for the beads to match up and make the second strand of your keyring. They keyring you made is 12 base pairs long, but the whole of the human DNA (inside every single cell in your body) is 6 billion base pairs. If your DNA was the same scale as this keyring, the DNA from one cell would stretch almost around the world! (36,000km – world circumference is 40,000km).
Key learning outcomes	· DNA replication and mitosis · The four base pairs of DNA

Risk Assessment	Usual care to be taken with scissors.
Scientific theme/topic	DNA
Where should this be packed away to?	Demo room

Demonstration name	Eating with enzymes
Equipment checklist	· Bread · Potatoes · Glucose soln · Lactose soln · Lactase · Glucose test strips · Iodine (test for starch) soln · Plastic tubes · 1ml pipette · Mortar and pestles · White tiles · Liquid waste box · Solid waste bin · Paper towel

What to do/instructions	There are three parts to this exhibit: Action of Amylase in saliva on starch, Action of Lactose on various sugars, Testing for proteins(possibly action of protease) 1) Get people to put a bit of sliced bread in their mouth and chew ask them not to swallow but to report what they are tasting (sour, sweet bitter etc). Whilst they are doing this drop some iodine on some bread and potato to show the presence of starch; optionally test some fruit to show no starch. By this time some people should be reporting a sweet taste, explain that an enzyme in their saliva has broken down the starch. Go on to show that some mushed bread or mushed potato do not show much glucose whereas boiled potato has some using test strips, you can do a control of glucose solution. 2) Use glucose test strips to show difference between Glucose, sucrose and lactose solns (only first changes colour). Lable two tubes, one lactose + enzyme one sucrose + enzyme, add 500ul of appropriate sugar to each plus 20ul of lactase enzyme, put in hot block at 37^{o}C for 3 min. Retest and the lactose should now show glucose the sucrose not. 3) Test various foodstuffs with bradford reagent, only those containing protein should turn blue. (I might yet try to set something up with protease but fear the digest time may be too long.)

What's the science behind this?	The three large molecule nutrients in your diet are Polysaccharides (starches), Lipids (triglyceride fats) and proteins; all of these need to be broken down by enzymes in the digestive system to be able to be absorbed. This breakdown requires enzymes that specifically break down (digest) the large molecules into smaller ones: Starch > di-saccharides (sucrose, lactose, maltose) and monosaccharides (glucose, fructose, galactose) Triglycerides > glycerol and fatty acids Protein > amino acids 1) Bread and potato (raw & cooked) and bread will all contain starch which can be shown by putting a few drops of iodine (red soln) on them which will turn black as the iodine slips inside the large starch molecule. A paste of bread or raw potato will contain hardly any glucose as can be shown with a test strip. (boiled potato may show a small amount). A well chewed piece of bread will have started to be acted on by the Amylase in saliva and should after a while taste sweet. If someone can be persuaded to 'drool' some of the paste out then a test strip should show an increased amount of glucose. 2) Lactase is an enzyme that cleaves the Glucose – Galactose bond in Lactose to release free glucose, it is specific and will not cleave the glucose – fructose bond in sucrose. Many people lose the ability to produce lactase as the mature and become lactose intolerant, this is the norm in some populations such as Japan 3)

Key learning outcomes	· Digestive enzymes are specific for the food type that they are breaking down. · The digestive process starts in your mouth · The activity or production of some enzymes can change during a lifetime and possibly cause disease.
Risk Assessment	Refer to YSC workshop 'Extract your own DNA' for more information on the risk assessment.
Where you can look for more info/links	http://brilliantbiologystudent.weebly.com/iodine-test-for-starch.html http://chemistry.elmhurst.edu/vchembook/548starchiodine.html
Scientific theme/topic	Enzymes, digestion, food types
Where should this be packed away to?	YSC

Appendix D: Capital Engineers Gallery Pack

Capital engineers

Gallery activities – information for teachers

MUSEUM OF LONDON DOCKLANDS

Teachers' notes

These activities help your pupils build on their session with Isambard Kingdom Brunel through exploration of the Thames Highway, First Port of Empire and New Port, New City galleries. They are designed to focus their time in the museum through guided looking, talking and role-play.

Our aim is that pupils should engage with the museum exhibits rather than worksheets.

You can choose to distribute all the activity cards, or select those you feel are most appropriate for your class. It is possible to keep the class in one gallery at a time, or set groups off on their own with an accompanying adult. Make sure each adult has a copy of the activity.

Please bring a camera to photograph your pupils at work. You'll see that many activities suggest that pupils are photographed, which can be a reminder of their visit as well as a way of recording their work. You could even video their role-plays.

Please chip in with further ideas and support to help the activities go well on the day – if you come up with something that works really well, please feel free to share it with us so we can add it to the pack. Email it to learning@museumoflondon.org.uk or add it to your visit evaluation.

Activity sheet

Capital engineers

Around the building

MUSEUM OF LONDON DOCKLANDS

The Museum of London Docklands

Outside the museum

No 1 Warehouse is part of the original West India Docks complex which opened in 1802. The complex was a major feat of engineering and was the largest building project in the world at the time. It was the first of the dock complexes in London to be built.

The Isle of Dogs, where you are now, was very marshy so few people lived here before the docks were built.

The West India Docks were built to house produce from the West Indies, like sugar, rum, coffee and bananas.

The people who designed the docks and the warehouses had to consider:

- how goods would be unloaded from the ships
- how they would get the goods into the warehouses
- how to keep the goods safe in the warehouses.

What can you see on the outside of the building that would help solve these problems?

Sketch some of the things you can see and note down what you think their purpose is.

Inside the museum

What are the main materials used in the construction of the warehouse?

Look closely at the floor in the galleries. It slopes very gently towards either side of the building. How would this help people unloading barrels of sugar and rum from the ships?

Try putting a pencil on the floor to see which way it rolls.

Capital engineers

3rd floor foyer

The Rhinebeck Panorama

This painting shows what London looked like from the air in 1806.

How do you think the artist got up so high?

How might you take a similar picture today?

The panorama would have been displayed on a curved wall so that the viewer would feel as if they were really flying above London. What differences would you see from the air above London today?

Look carefully at the panorama.

How many bridges can you see in the engraving?

How do people decide where to build bridges?

How many bridges over the Thames do you think there are in London today? Write down your estimates and then check the answer back at school.

Capital engineers

Thames Highway gallery

MUSEUM OF LONDON DOCKLANDS

London Bridge 1440 – activity sheet 1

Look at the model of London Bridge in 1440.

This was the first London Bridge to be made from stone.

Why did they decide to use stone to replace the wooden bridge?

What properties does stone have that make it a good material for building bridges?

On top of the bridge there are shops and houses. Would you like to have lived on London Bridge?

Some of the houses have small rooms built out over the river. These are the **privies** or toilets.

Why do you think they built them on the outside of the houses?

The privies helped to make London Bridge the healthiest place to live in London, but what happened to the river?

Capital engineers

Thames Highway gallery

MUSEUM OF LONDON DOCKLANDS

London Bridge 1440 – activity sheet 2

Find the drawbridge.

It could be raised to allow ships to pass through so they could unload their cargoes at wharves on the other (upriver) side of the bridge.

Which bridge in London can be raised today to allow ships through?

Why do you think it might have been important to have a drawbridge on London Bridge?

What other buildings can you think of that might have drawbridges?

If you were building a bridge today, what do you think it would need to have?

Think about the traffic in London today compared to 1440. How do people travel today?

Capital engineers

Thames Highway gallery

New Horizons

Look at the map of journeys made by famous explorers between 1400 and 1600.

Who travelled the furthest?

Whose journey do you think took the longest?

New, larger ships that could carry more supplies and improvements to maps and charts meant that it was possible for explorers to travel further.

Why do you think these explorers travelled so far?

Why was it important to find new countries and sea routes?

Look at the map again. Why are all the journeys to the south and not to the north of the world? Is it possible to travel around the top of the world?

Make a list of the things you would need to take with you on your journey.

Capital engineers

Thames Highway gallery

London Bridge 1600

Find Nonesuch House.

Nonesuch House was built from wooden frames that were made in Holland and carried to London on boats.

What makes it different to other houses on London Bridge?

Who do you think might have lived in a house like this?

There are two men standing to the right of Nonesuch House.

What do you think they are talking about?

With a friend, make up a conversation about this amazing building and role-play it for the rest of your group.

Find another building on the bridge that was built in a similar style to Nonesuch House.

Why do you think the windows in the wooden houses are so small?

Why are the windows in Nonesuch House much bigger?

Capital engineers

First Port of Empire gallery

MUSEUM OF LONDON DOCKLANDS

The Great Stink

For hundreds of years the Thames was used as a sewer, with all the city's drains emptying into it. It was also the main source of drinking water!

What do you think it smelled like?

Look at the cartoons and photographs. What do they tell you about how the Thames became so polluted?

Imagine you live in London in 1832. What do you think should be done about the river to make it better?

Discuss it with your group and make a list of three improvements you would make.

1.

2.

3.

Activity sheet

Capital engineers

New Port New City gallery

MUSEUM OF LONDON DOCKLANDS

20th century engineering

The 20th century saw a lot of engineering work in London.

Explore this gallery and find:

- the Thames Barrier
- the Docklands Light Railway
- 1 Canada Square
- containerisation at Tilbury Docks
- Millennium Bridge
- the Jubilee line extension

Look at the displays and in your group, choose the one that you think is the most important piece of 20th century engineering.

Share your choice with the rest of the class and explain why you chose it.

Have all the groups chosen the same thing? Why not?

Activity sheet

Appendix E: Preamble for Trolley Testing (Unformatted)

Come try some new family activities!

We’re a research team from Worcester Polytechnic Institute, a university in the United States. We’re working with the Museum of London Docklands to design activities for families. We are here to observe people’s interactions with these activities, which will help us develop better activities. Please let us know if you have any questions or concerns. Thank you for your time! Have fun!!

Appendix F: Activity Comment Card

What encouraged you and your family/group to join in this activity?

What was the favourite aspect of this activity for you and your family/group?

Did you find the content of this activity interesting? Why?

Were you given the right amount of information to help you take part in this activity?

What would make this activity more enjoyable for you and your family/group?

Did the activity help you learn together as a family?

What's the single most important thing you will remember about this activity?

Other comments, questions, and thoughts:

Thank you for participating in this activity! We hope you found it enjoyable! Your feedback is greatly appreciated. If you have any questions, please contact us at mol-17e4@wpi.edu Enjoy your time at the Museum of London Docklands!

Appendix G: Volunteer Packs for Prototype Activities

Stinky Sewers

	• Embankment model

Equipment checklist	• House models • ¾ in. PVC pipes, elbows, tees • 1 ¼ in. PVC pipes, elbows, tees • Water-filled straw models • Marbles, 1cm diameter
Overview	The aim of this activity is for families to learn how sewer systems work by interacting with and observing small models of water-filled pipe networks. Then, they can design their own sewer system using the pipes, connectors, and terminals provided. To test their designs, families can drop marbles into the holes included in the house models. This allows them to see where water might get stuck along the way.
Instructions and Suggestions	Feel free to facilitate the activity in your own way using guidance from this section, and the narratives from the next section. If you're looking for ideas, here's one example of how to run the activity: You can start by giving families an overview of the activity, or you can start with some background information Try to direct families towards the water filled models first, and ask them to shake and rotate them about. Ask them questions about how fast the water moves in each structure, and where the water tends to get stuck. Then, challenge them to build their own sewer system, connecting a small assortment of houses to the included model of the Embankment. Families might be drawn to the PVC pipes first. In this case, you can show them the water filled models while they use the pipes or after they finish. Depending on the ages of the participants, it may be helpful to show briefly how all the components work before presenting the design challenge. Whilst participants are making their structures, you can share with them the facts and background information below, or ask them questions about what they're doing. Some examples of questions could be: Why do you think the sewage system is important? How does sewage get dealt with in your home? Why do you think the pipes aren't all the same size? How would you figure out the size of the main pipe? Do you think the Thames embankment will ever need to be expanded? What do you think would happen if the sewer system ever overflowed? (The system is designed to vent directly to the river in case of overflow) Send families to find out more about sewage in the galleries. Point out the information panel about Bazalgette.

Background information	Up until 1870, the Thames was used as an open sewer, serving as the endpoint for all the raw sewage that flowed openly through the streets of London. The presence of faecal matter in the streets and riverbank caused 3 large outbreaks of cholera, killing almost 15,000 Londoners in total. During one hot summer in 1858, the heat caused the wastewater to smell so badly that citizens avoided the river, and Queen Victoria and Prince Charles had to cut their pleasure cruises short. Even Parliament considered moving away for the season! This event was eventually dubbed "The Great Stink" by various newspapers. In response, civil engineer Joseph Bazalgette proposed the design for the Thames Embankment, which was a colossal sewer pipe that moved the drainage away from the centre of London. Years later, treatment plants would be installed on the embankment to clean the wastewater before draining it into the Thames. When Bazalgette sat down to figure out how wide the main pipe should be, he estimated "a healthy amount" of sewage production for the Metropolitan area, calculated the appropriate diameter, and then doubled it. Now that's some gross math! If Bazalgette didn't double the pipe diameter, the Thames Embankment would have overflowed in the 1960s, instead of remaining fully functional even to this day. If families ask why their marbles become stuck, you can say that when an object begins to roll down a hill, it possess a quality known as *potential energy*. The laws of gravity show that an object can't gain more potential energy than what it started with (conservation of energy), which is why some marbles get stuck at dips and u-bends.
Key Learning Outcomes	• Creatively and collaboratively building structures/shapes • How to make scientific observations • Using scientific observations to influence/refine designs • Understanding of the importance of the sewage system for London and its relationship to our personal lives today • Understanding the relationship that the London sewers have to the river and docklands areas. • A perception of science as accessible and fun • Use concepts of gravity and potential energy to explain why water can't flow uphill
Risk Assessment	Care should be taken when decoupling pipes. Some may be tighter than others, though measures have been taken to make sure they're not too tight.
STEAM Areas	**S** - Families observing the behaviour of fluids in a tubular network **T** - A design challenge is given to connect a neighbourhood using a network of pipes **E** - Testing the structures using marbles, refining design as necessary

Ship Shapes

Equipment checklist	• Test Frame • Prebuilt Models • Blocks to build ships • Paper and writing utensils to trace ships
Overview	In this activity, families will be able to match ship hull shapes to the time periods they were prevalent in. There will be a laminated timeline with a few facts for each date for hints. Families will then have the option to design their own ships, possibly what a future ship might be like, either based on the designs of past ships (names of ships and their shapes will be included on table) or from their imaginations. They will test their designs in the "water frame" to see how the water reacts and moves around the frames.
What to do/instructions	First, the three pre created shapes will be tested in the frame. (Steamer, tea clipper, fishing sailboat) Each shape reacts differently with the water strand analogues and should feel different when moving through. First the shapes should be placed flat upon the ribbons. This leads to a discussion about how wider and larger shapes are more stable and less likely to sink in a storm. However, larger ships sit lower in the water. What problems may this cause? (Discuss the Great Eastern Hitting the Great Eastern Rock in 1862)(The rock was named after this incident)(larger ships have trouble making it up shallow rivers) Next the shapes should be inserted point first in a way so that they move ribbons out of the way. The smallest point (fishing boat) should move almost no ribbons out of its way and slip into the gaps. The large rounded front (great eastern) however would push a lot of ribbons down but not move many out of the way. The ship that is in between (tea clipper) would move a couple of ribbons out of the way but mostly cut through. After feeling how the different shapes feel when moving through the strands it should be asked why they think certain shapes move easier. Why would they ever need something that moves slower? (fuel saving, more reliable) (lower crew to cargo ratio, few crew for lots of cargo) Why do certain goods have to be moved quicker? (goods spoil, the first and fastest batch of tea is worth the most money, held races in which there was a prize to the first tea clipper that got back to port carrying a cargo of tea) (high crew to cargo ratio, lots of crew for little cargo) Talk of the use of each ship • Tea Clipper - move tea fast between locations • Steamer - move large quantities slowly and reliably • Fishing boat - quick fishing boat

<table>
<tr><td></td><td>Next invite the guests to build and test their own types of boats using the velcro blocks using the following prompts:
1. Build a ship that has to carry as much as possible but speed doesn't matter
2. Build a ship that has to move fast but capacity doesn't matter
3. Build a ship that has to transport large quantities but still move quickly
4. Build a ship of the future
5. Build any ship you would like

At the end of their designing the guests have a chance to trace their designs on paper to take with them.</td></tr>
<tr><td>Narratives</td><td>• Owner of a shipping company
  ○ You have to move a number of different goods and need a variety of ships to do so.
• Ship Designer
  ○ You were hired by a rich family wishing to ship goods across their many owned company locations. They want you to design a ship for moving their goods.
• Royalty running a country
  ○ You have to move a number of different goods and need a variety of ships to do so.
• Captain of a ship trying to make a living
  ○ What ship would you rather be on? A long long voyage that makes a large sum of money or multiple shorter ones to see your friends and family back home.</td></tr>
<tr><td>Risk Assessment</td><td>Don’t pull on ribbons too hard or rubber bands may snap</td></tr>
</table>

Packing Puzzle

Equipment Checklist	• Cargo Tiles • 3 Ship Outline Mats
Overview	Design the floorplan of a ship by fitting the tiles into the outline of the mats. The mats can be used separately or in correlation with each other to represent different floors of the ship. There are three levels of difficulty: <u>Easy</u>: fit as many tiles as you can into the outline of the ship on your mat <u>Medium</u>: fit tiles into the outline of the ship on your mat, but be sure to follow Rule 1 on all of the tiles! *Rule 1 restricts the placement of the tile* <u>Hard</u>: fit tiles into the outlines of the ship using all of the mats. Be sure to follow both Rule 1 and Rule 2 for the tiles that have them! *Rule 2 restricts the placement of the tile for vertical packing*
Instructions and Suggestions	Your role is to guide families through the activity (outlined in the 'Overview' section above) with an interactive narrative. Give facts and ask questions as the families are working through the activity to give them a better understanding of the various factors that contribute to ship packing. You can choose to start with a brief overview of the activity, or you can begin with a narrative or questions. It is important to have the families making guesses and thinking about why packing was important and what challenges the dockers may have faced. For question ideas, see the 'Suggested Questions' section below. Be careful not to overwhelm the families when explaining the various ways to perform this activity. It could seem rather intimidating to be presented with all of the possible ways at once. It may be a good option to allow them to perform the activity with easy or medium before explaining the multiple floors. Point out to the families that some of the tiles have a scent and others have actual goods in them (which are sealed to protect against allergens). See if you can encourage them to speculate on why some cargo needs to be kept cool, why some items should be stored higher, and why certain goods should not be stored near each other. (See the 'Suggested Questions' Section for in depth analysis.)* If families seem to be talking amongst themselves and leading the activity independently, it is ok to step back and not take as large a role in directing the activity.
	You can prompt the family with one of these statements or questions to guide them through the activity with an interactive narrative developed by questions and facts.

Narratives and Facts	*Have the families speculate about what it might have been like to work in different positions on the docks. What skills might you need and what tasks would you have if you were a…* Manager: knowledge of the different ships and trade routes, understanding of ship packing constraints, ability to decide who gets work Physical Laborer: strength and endurance to carry heavy cargo, ability to take orders, understanding that work is not guaranteed Traveling on a ship was very difficult. You would be away from you home and family for possibly a long time, but you would get to see many new places. Scurvy, a sickness from not enough Vitamin C, would make them very ill. ***Do you know how they kept this from happening?*** Living on a ship meant spending a large amount of time looking out over the ocean. ***What kinds of things do you think you might have seen?*** *Would you want to live on a ship? What might you enjoy most?* *Animals such as elephants were often transported, what do you think happened to their manure?* Since, manure produces methane gas, it had to be kept in a high location to prevent gas build up that could lead to an explosion if a spark was introduced. For this reason, it was stamped with the acronym for Stow High In Transit.
Suggested Questions	What challenges might the dockers have encountered with packing and transporting various cargo? Animals? Meats? Produce? Why is it important to plan out how to pack a ship instead of just putting everything on? How might the order of destinations affect the way the ship is packed? How does weight and balance affect packing? How could the shape of the different containers vary the way they can be stored and packed? *Helpful Questions for Packing Why should fish not be kept near fabrics or fresh fruits? *Hint: think about how raw fish smells.* Why would it be more practical for the cannons to be higher up? *Hint: Where would you want to hit another ship with a cannon?* Why can't the elephants be stored near the food or the wool? *Hint: How do elephants smell? Would you eat food if it was next to you?*

	Why should rum not be stored near wool? *Hint: When you tilt a glass, what happens to the liquid in it?* Why does fresh food like fish and fruit need to be kept cold? Why does manure need to be stored higher? Elephants? *Hint: store high in transit; how would the elephants get below deck?*
Risk Assessment	Though they are sealed, be sure to inform families that some of the cargo tiles contain possible allergens. Be careful to not puncture the covers for the allergens, and if a cover were to be punctured, remove the cargo tile from the activity.

Key learning outcomes	• Fluid dynamics
	    o How the deformation of water affects ships' movement (how the shapes of ships affect movement of the water)
	• Considerations that designers/engineers must make when designing ships
	• Design Methods
	    o Prototyping, testing, and revising
	• Inspires children to further explore how shape can affect movement in a fluid

STEAM Areas	S - Fluid Dynamics T - Designing ships for different requirements A - Designing your own ship

Appendix H: May Half-Term Visitor Tallies

Time: 10:00-12:30
Activity: Stinky Sewers

Under 7		7-11		Over 11	
1		10		1	
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
7 +kids: 5	W/ child: 12 Alone:	Under 7: 1 7-11: 5 Over 11:	Under 7: 7-11: 4 Over 11: 1		2 possibly older sister and her friend 1 adult when two were around, moms friend possibly?

Passerby groups: 8
Groups deterred by other group: 1
Multiple groups together: 1

Time: 12:30-14:30
Activity: Stinky Sewers

Under 7		7-11		Over 11	
3		8			
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
6 +kids: 3	w/ Child: 9 Alone: 1	Under 7: 3 7-11: 6 Over 11:	Under 7: 7-11: 2 Over 11:		3

Passerby groups: 10
Deterred by other groups:
Multiple groups together:

Time: 14:30-16:30

Activity: Ship Shapes

Under 7		7-11		Over 11	
		2			
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
1 +kids:	w/ child: 1 Alone:	Under 7: 7-11: 1 Over 11:	Under 7: 7-11: 1 Over 11:		1 (only in group probably nanny)

Passerby groups:
Deterred by other group:
Multiple groups together:

Time: 10:00-12:30
Activity: Ship Shapes

Under 7		7-11		Over 11	
7		4		2	
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
4	6	6	8	2 1 asleep baby	1

Passerbys: 9
Deterred by other group: 1
Multiple groups together: 1

Time: 12:30-16:30

Under 7		7-11		Over 11	
10	15	5	8		3
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
8	11			2	4

Passerbys: 5
Deterred by other groups: 2
Multiple groups together:

Time: 10:00-12:00
Activity: Packing Puzzle

Under 7		7-11		Over 11	
Male	Female	Male	Female	Male	Female
5	1	4	4		
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
5	9			1	2

Passerbys: 6
Deterred by other group:
Multiple groups together: 1

Time: 12:00-14:00
Activity: Stinky Sewers

Under 7		7-11		Over 11	
Male 5	Female	Male 8	Female	Male	Female
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
5	7 Alone: 2 women			1	3

Passerby Groups: 6
Deterred by other groups: 1
Multiple groups together:

2 women showed interest and then asked the boys to show them the activity

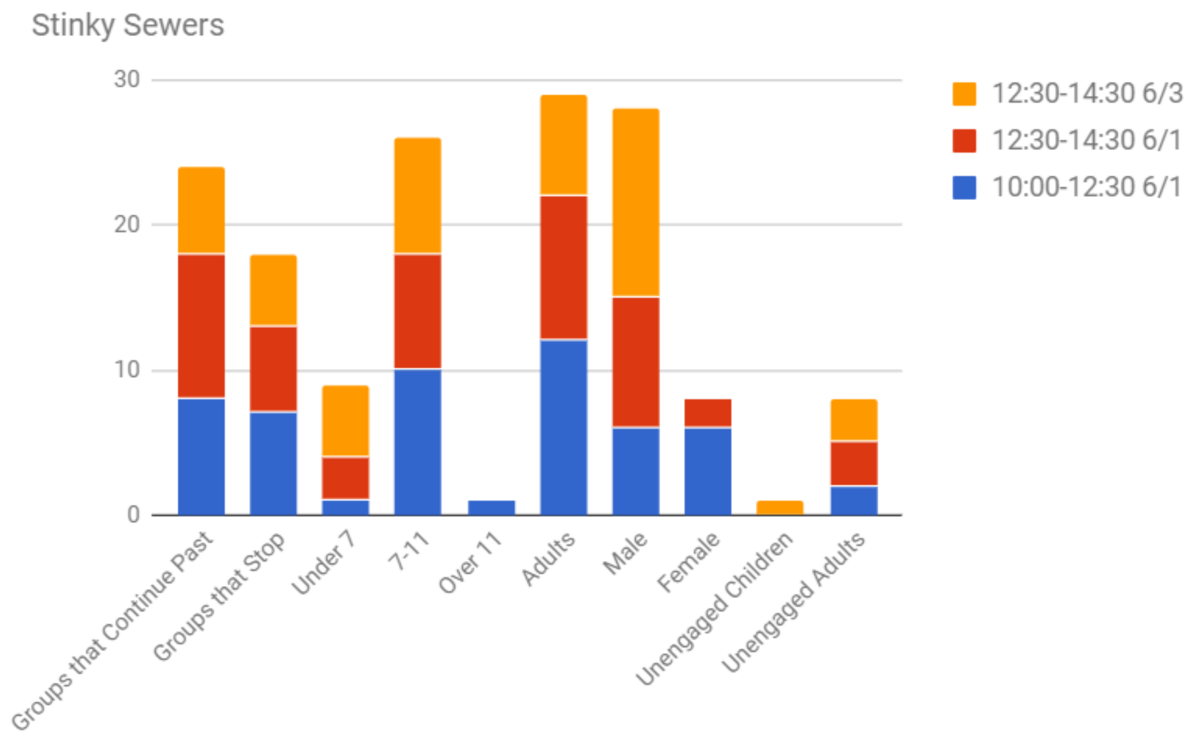
Time: 14:00-16:00
Activity: Ship Shapes

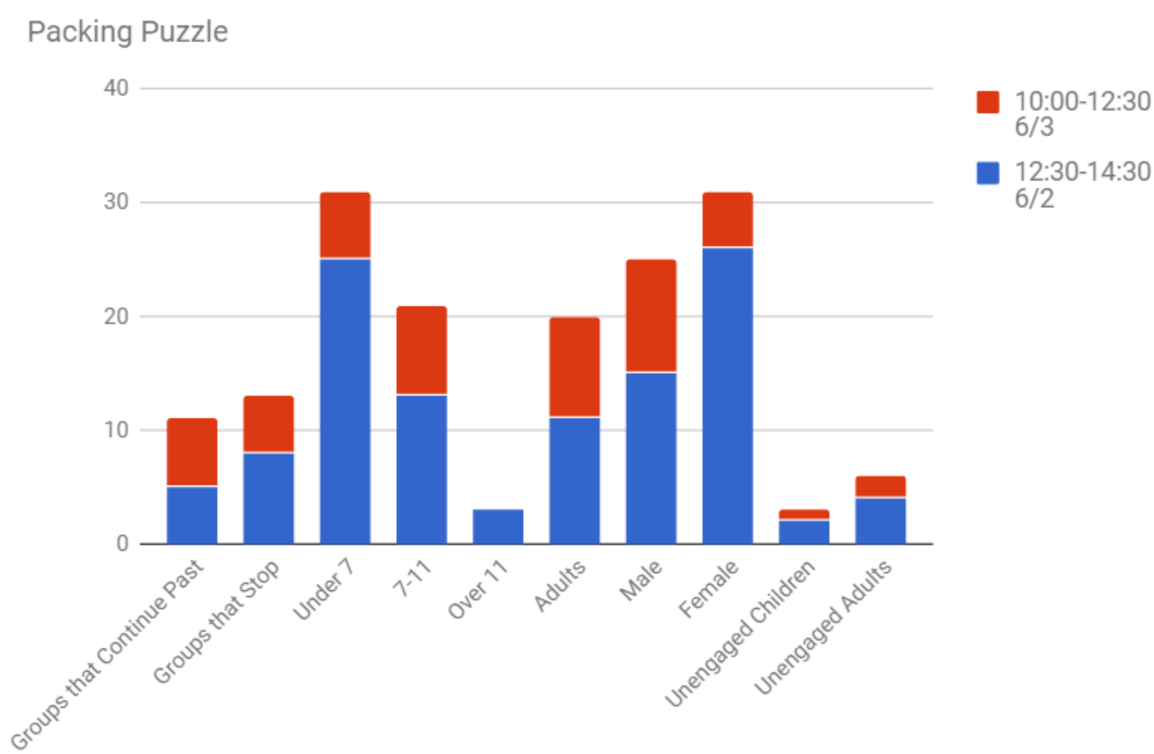
Under 7		7-11		Over 11	
Male	Female	Male	Female	Male	Female
1	1	1	2		
# of Groups	Adults	Male	Female	Unengaged Children	Unengaged Adults
1	4			1 (baby)	1 (with baby)

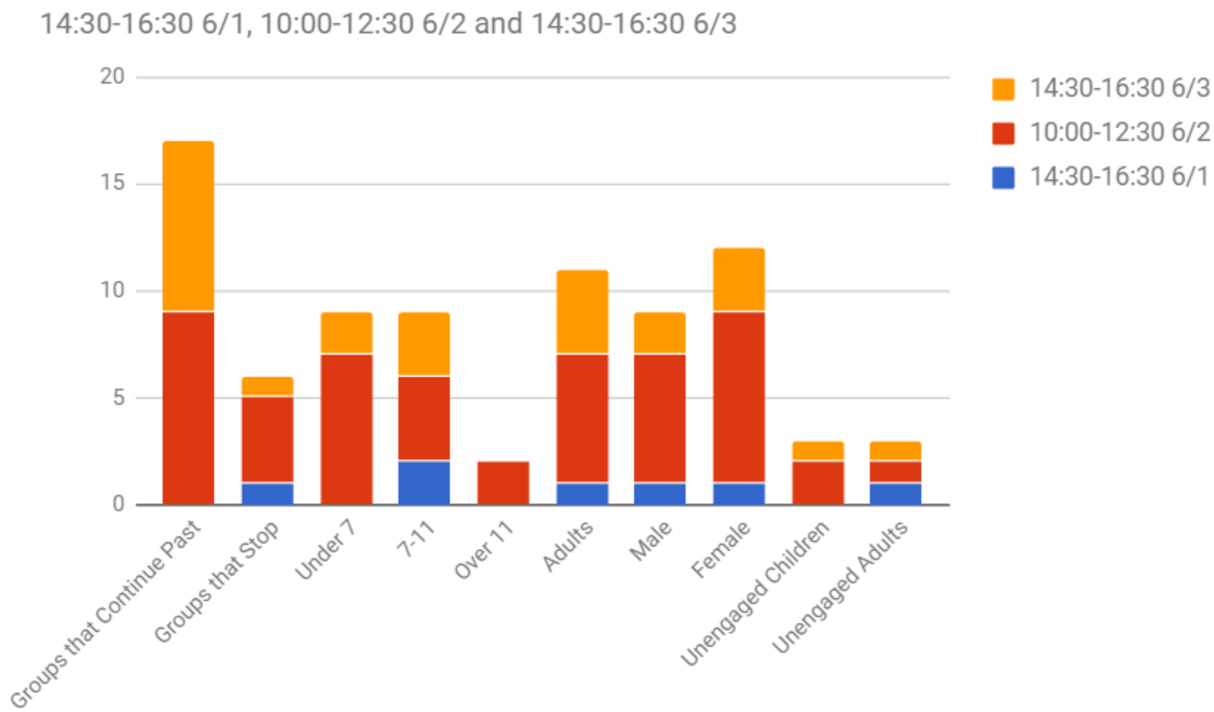
Passerby groups: 8
Deterred by other groups: 1 - mother seemed deterred
1 - stood and looked then left
Multiple groups together:

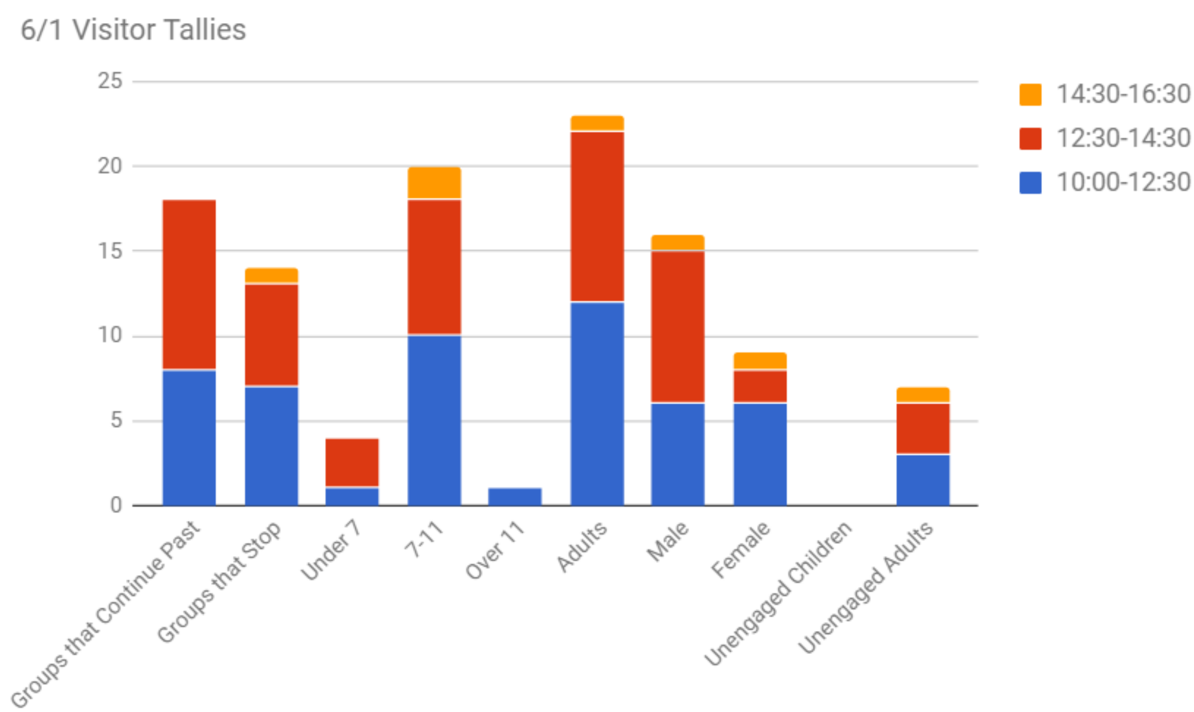
Good questions by the kids (good insights when knowing the slow/strong and the fast, able to figure out the middle one is fast but still strong)

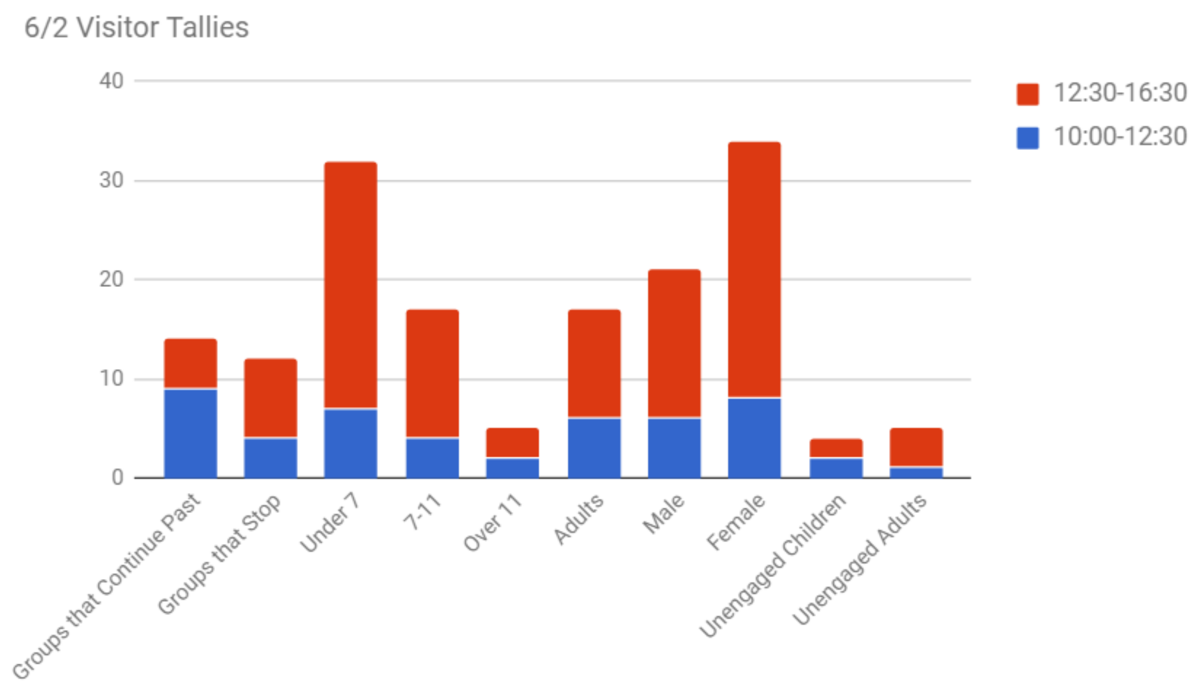
Appendix I: Additional Visitor Tally Visualizations

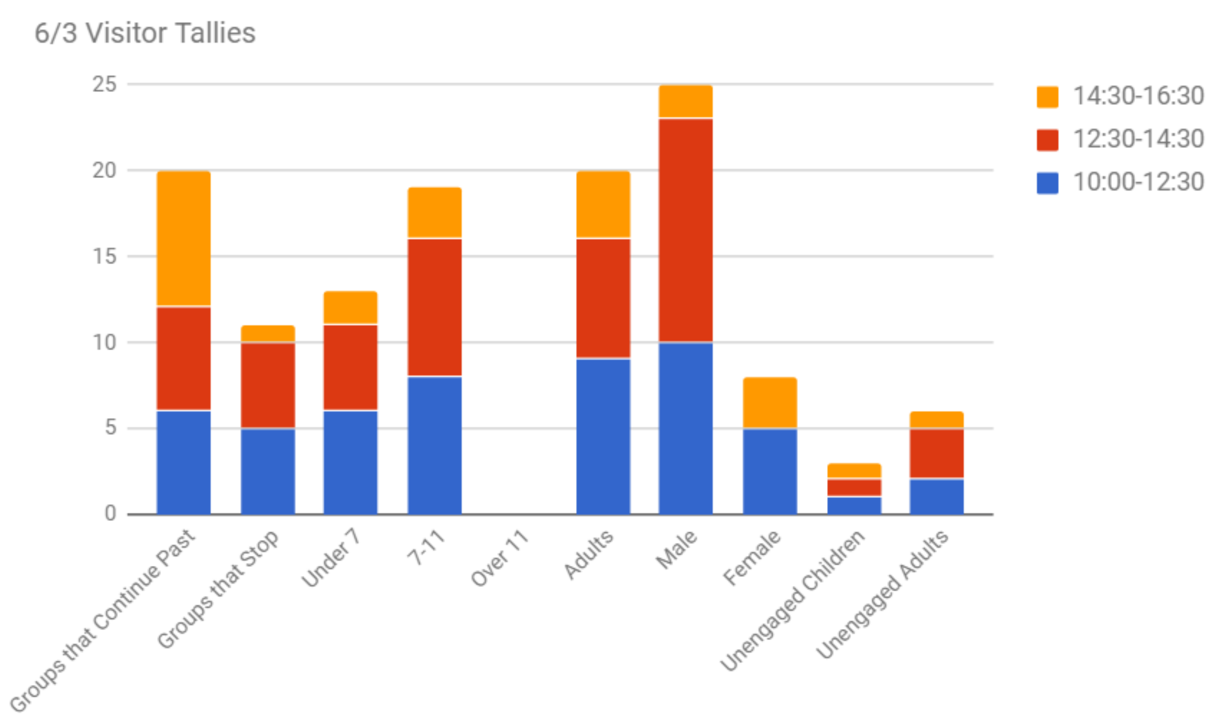


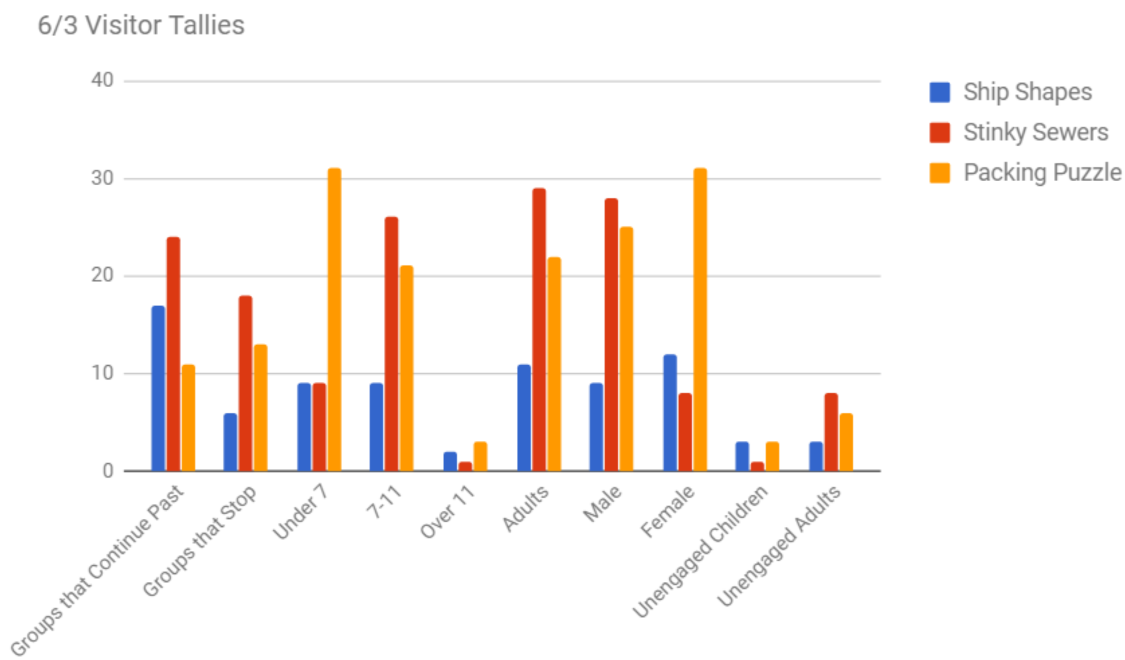


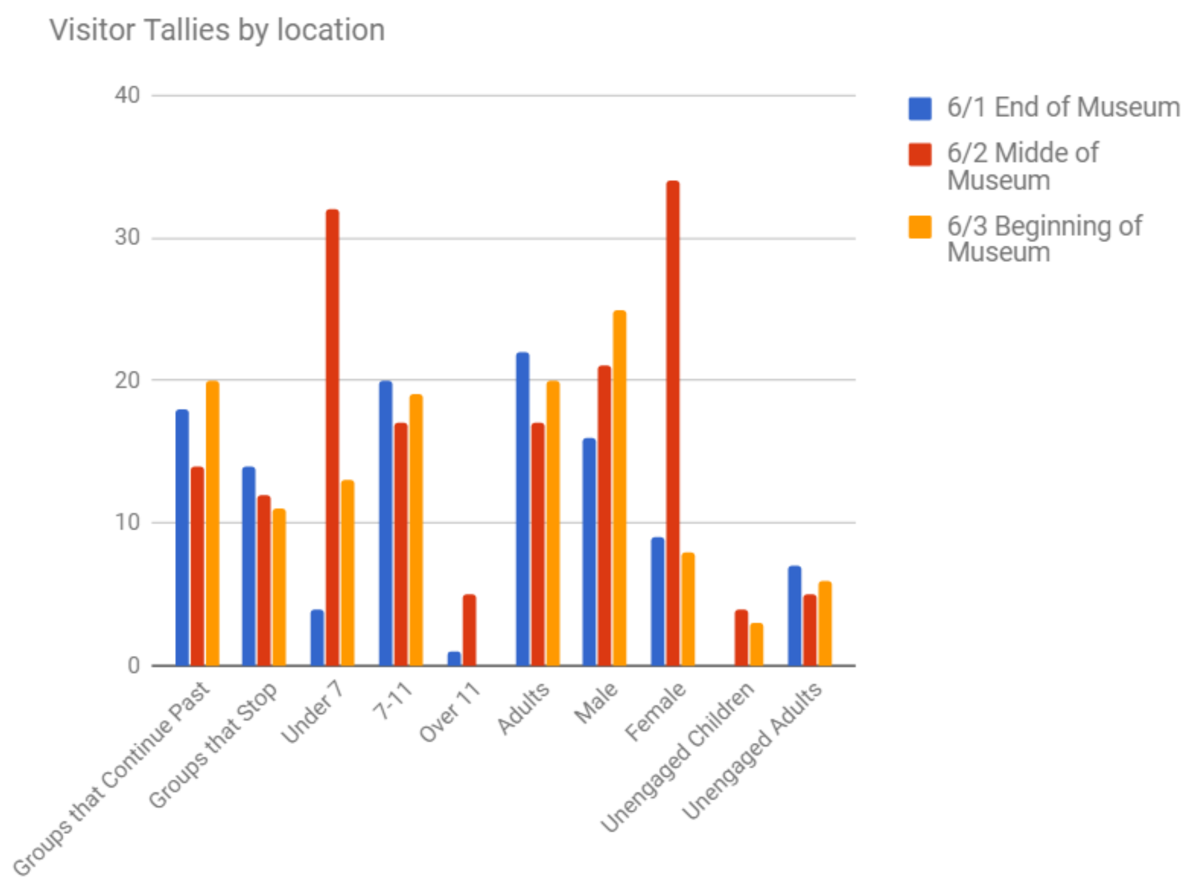

14:30-16:30 6/1, 10:00-12:30 6/2 and 14:30-16:30 6/3
20
15
10
5
0
14:30-16:30 6/3
10:00-12:30 6/2
14:30-16:30 6/1
Groups that Continue Past
Groups that Stop
Under 7
7-11
Over 11
Adults
Male
Female
Unengaged Children
Unengaged Adults

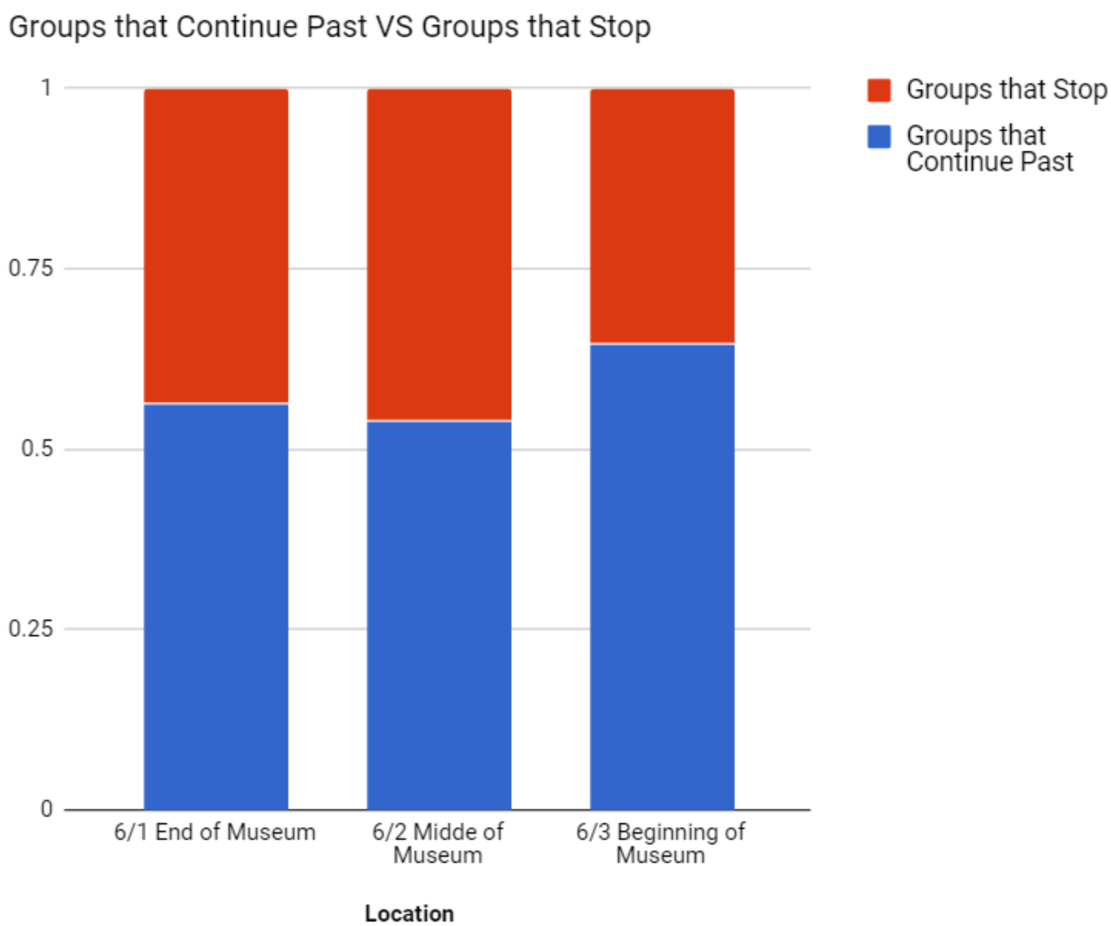

6/1 Visitor Tallies
25
20
15
10
5
0
14:30-16:30
12:30-14:30
10:00-12:30
Groups that Continue Past
Groups that Stop
Under 7
7-11
Over 11
Adults
Male
Female
Unengaged Children
Unengaged Adults


6/2 Visitor Tallies
40
30
20
10
0
12:30-16:30
10:00-12:30
Groups that Continue Past
Groups that Stop
Under 7
7-11
Over 11
Adults
Male
Female
Unengaged Children
Unengaged Adults


6/3 Visitor Tallies
25
20
15
10
5
0
14:30-16:30
12:30-14:30
10:00-12:30
Groups that Continue Past
Groups that Stop
Under 7
7-11
Over 11
Adults
Male
Female
Unengaged Children
Unengaged Adults


6/3 Visitor Tallies
40
30
20
10
0
Groups that Continue Past
Groups that Stop
Under 7
7-11
Over 11
Adults
Male
Female
Unengaged Children
Unengaged Adults
Ship Shapes
Stinky Sewers
Packing Puzzle


Visitor Tallies by location
40
30
20
10
0
Groups that Continue Past
Groups that Stop
Under 7
7-11
Over 11
Adults
Male
Female
Unengaged Children
Unengaged Adults
6/1 End of Museum
6/2 Midde of Museum
6/3 Beginning of Museum


Groups that Continue Past VS Groups that Stop
1
0.75
0.5
0.25
0
Groups that Stop
Groups that Continue Past
6/1 End of Museum
6/2 Midde of Museum
6/3 Beginning of Museum
Location

Appendix J: Full STEAM Ahead! Gallery resources for teachers

Full STEAM ahead!

Gallery activities - information for teachers

Teachers' notes

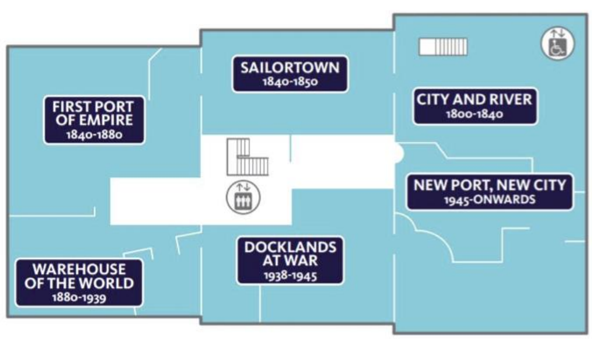
These activities are designed to allow your pupils to understand the science, technology, engineering, mathematics, and art/design connections to the River Thames. Additionally, they will understand that the river continues to be an important part of life in London, and how it shapes their daily lives.

Our aim is that pupils should engage with the museum exhibits and each other with talking and activities rather than with worksheets.

This prototype resource pack was designed by engineering students from Worcester Polytechnic Institute in the United States. They are conducting research with the Museum of London Docklands to develop STEAM-based educational materials for families and schools. The team will be observing and taking notes throughout the day, and they will also be available to answer any questions you may have during your visit.

Feel free to photograph your pupils at work. This can be a reminder of their visit, as well as a way of recording their work. The research team would also appreciate some photos accompanied with signed permission from the parents of students involved for inclusion in their presentation.

As the pack is currently in the prototyping stage, please let the team know what can be improved, and please chip in with further ideas and support to help the activities go well on your visit. If you come up with something that works really well, let us know after your visit, or send an email to mol-17e4@wpi.edu.

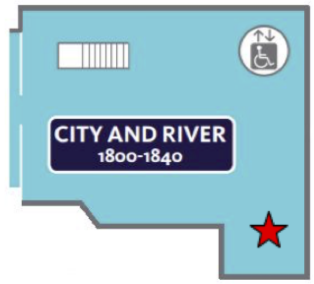


Activity Sheet

Full STEAM ahead!

City and River gallery

New London Bridge



Story: Until the 18th century, the River Thames would freeze over in the winter, and festivities known as Frost Fairs would take place on the ice.

Why do you think rivers are less likely to freeze than ponds and lakes? *Hint: compare water movement for each type of body of water*

What are possible benefits of a river that freezes? Of one that doesn't?

Why are bridges important? What do you need to consider when building a bridge? *Hint: effect on surroundings, i.e. the river, and ship passage*

Activity: *5 arches:* ask 10 students to form a bridge with five arches, standing. Now have the rest of the students try to "flow" through these arches. *3 arches:* repeat the process for five arches, except with only six students. Make sure the 'bridges' are the same length!

This activity demonstrates how bridges can have a significant effect on water flow. In 1831, old London Bridge was demolished and replaced by a bridge with wider arches, thus allowing the water to flow more freely. Since the water is now constantly moving, it is much less likely to freeze.

How do bridges and ships affect the way each other are designed?

Activity: Split into 2 groups: bridge and ships. *Bridge task-* agree on height and width for the arches, then set up like in the previous activity only with the decided dimensions. *Ships task-* (could have 1 big ship or smaller ships for each arch) decide if they'll be tall, short, wide, or narrow ships, then try to pass under the arches of the Bridge group. *Can the groups work together to make a new design that might work better? Would making a drawbridge help?*

After this activity, can your students add to their previous answer?

How would a drawbridge affect ship passage? How could a ship change to fit under more bridges? *Hint: the Thames Barge folds its mast*

Why might it make more sense to build tunnels rather than more bridges? *Hint: think about the impacts demonstrated with the activities*

Full STEAM ahead!

City and River gallery

Model of St. Katharine Docks

Story: In the docks and out on the sea, ships had to communicate between each other. Sailors spoke many different languages, and docks were noisy, busy places. It was often impossible to communicate verbally between ships.

What forms of communication have you heard of them using? (flags, flashing lights, whistles (demonstrated in the Sainsbury gallery on the second floor))

Through this part of the gallery students must find a way to communicate to each other through nonverbal means!

Activity: The goal is to have students come up with their own communication methods while completing different challenges. Allow them only 1-2 minutes to complete each task

- First, arrange in order by day of the month each person was born (1st of any month, 2nd of any month, 3rd of any month etc).
- Next, group by favourite colors
- Finally, gather by favourite type of music.

The first is the easiest due to a pre established way of communicating numbers to each other. The colors were a little more difficult but can be pointed to around the gallery. The genres of music should have been the hardest.

At the end of each round have each group go around and say what they thought they were in.

Was this challenge easy/difficult? Why? Explain that it can be difficult to communicate without agreeing on a method first.

Why is it important for everyone sailing to use the same communication method? For example, what might happen if different countries used different methods to communicate the same word. How could this create problems? *Hint: misunderstandings possibly causing fights or accidents*

What forms of communication do ships use now? (Satellite phones, radios, Morse code)

Activity Sheet

Full STEAM ahead!

City and River gallery

Rituals and Races

<u>Story</u>: Rowing boats were very common on the river. To row effectively, they needed to be able to communicate in order to work together effectively.

This was handled by someone called the *coxswain* (ˈkɒks(ə)n) who would call out "Row!" The coxswain ensured the rowers all rowed at the same time.

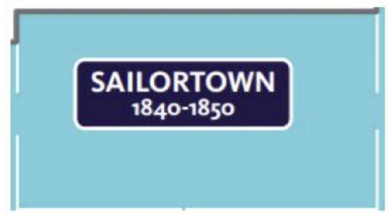
<u>Activity</u>: Arrange the students into two lines and ask them to row in time and in sync with each other. Have one of the chaperones, or one of the students, take the role of the coxswain, commanding the crew to row. When you are satisfied with your students' rowing skills, call "move" and encourage them to row together towards the start of Sailortown.

Why do you think rowing is used on the river but is not considered an efficient method for ships? *Hint: how do you feel after a long game of tag? (*Tiring, not enough man power but can operate in areas of the river with little to no wind)

Full STEAM ahead!

Sailortown & First Port of Empire gallery

The Great Stink



Story: In Victorian London, the Thames was used as an open sewer. All of the rainwater and waste flowed through the streets, which often drained directly into the river. This created a polluted river that stank and carried disease.

Guide the group through Sailortown and ask these questions:

Smell the air and look around. How would you describe this street?

What would happen if it rained? Where would the water go?

Find the kitchen. Do you see a sink? Do you see toilets in any of the houses? Where did the waste go?

Where do you think the water that people drank came from?

Would you want to drink the water? Why?

The fish that people ate also came from the river. Would you eat the fish?

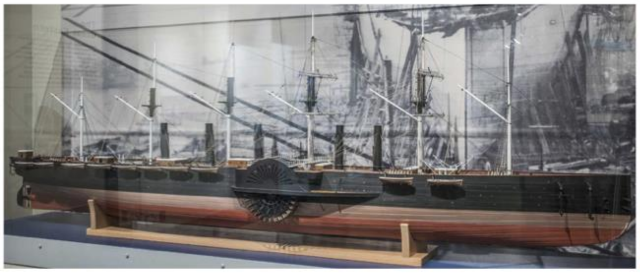
After exiting Sailortown, locate the display on The Great Stink.

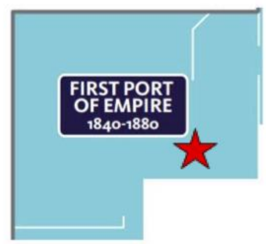
How were the problems that you saw in Sailortown resolved?

Full STEAM ahead!

First Port of Empire gallery

Blacksmith's Forge & the Great Eastern





<u>Story</u>: At the blacksmith's shop they would make tools and equipment for ships and dockworkers.

What sort of things would a blacksmith make for use on a ship? (parts, pulleys, swords, etc)

How does a blacksmith manipulate hard metals? (Heating metal in the forge makes it softer so it can be manipulated with various tools) The hotter the material gets, the softer it becomes and the easier it is to work with.

There are many complex and interesting reactions related to heating and cooling metals in different ways such as annealing, tempering, and normalizing. Each process causes the metal to take on different properties. (For tie in of research later or outside of school if students are interested)

Why do they need heavy hammers and tools? (metal is strong and hard to move, even while hot)

As ships got larger and more complex it became less practical for blacksmiths to make parts in the same ways. Look around the gallery for a machine that could manipulate metal even when it was cold and hard. (metal punch)

What else used steam power? Can you find something nearby? (Great Eastern)

<u>Science</u> <u>fact</u>! Metals have many different properties. *Malleability:* the ability to deform under pressure. *Ductility:* the ability to draw a metal into a wire. Look around the gallery. Can you think of any metals that are malleable? Ductile?

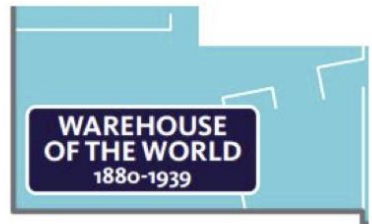
Activity Sheet

Museum of London Docklands 2017. This sheet is a prototype being tested for future development.

Full STEAM ahead!

Warehouse of the World gallery

Sampling Case



Story: As the docks grew in size and popularity, goods from across the world started arriving in the city.

Can you guess what kinds of goods might have been shipped at this time? *Hint: open the boxes and see if the smells give you any ideas*

How could a faster ship change the types of goods that could be transported? Can you find an example of a faster ship nearby? *Hint: it's a tea clipper*

Sugar isn't a crop that is able to be grown in London, yet you see it every day. How do you think it comes into the city?

Activity: Act out what sort of body motions you would need to make if you were moving a bag of sugar across the warehouse. What might make this task easier? *Hint: think teamwork and engineering* (more people in a chain? Tools?)

What kinds of tools might be useful for moving cargo? *Hint: check out Warehouse No. 1*

Everything that came into the docks had to be documented and approved. What do you think it was like to bring cargo into the docks? *Hint: have you ever been out of the country? How was it going through customs?*

Full STEAM ahead!

Docklands at War gallery

Target Thames & Melted Iron Column

Story: Due to the docks' importance to life in London, they were targeted by the German air force during World War II. Ships were damaged with magnetic mines, and aerial bombs threatened to destroy the docks.

A magnetic mine is a device that would explode when anything magnetic passed by.

What were ships in the 1940s constructed out of? Why would this have been a problem with magnetic mines in the river?

Science fact! *Ferromagnetism* is the tendency for iron to emit a magnetic field. Electric currents can neutralize this field, which is what naval engineers eventually did for their iron ships. This process was called *degaussing*, and it stopped the mines from exploding.

Guide your group to the melted iron column near the center of the gallery. Refer back to the Blacksmith's Forge.

What do you think happened to this column?

What do you think the column supported?

Why do you think only a part of the column melted?

How hot do you think it must have been to melt this? A lot of the melted column is still left standing. How fast do you think it cooled down?

Full STEAM ahead!

New Port, New City gallery

Modernization of the Docks

Story: As even more goods came into the docks, the old buildings that used to house them became too small and difficult to work inside. A new kind of dock building needed to be designed.

Have your group study the model of the New London Docks.

What can you see in the model that you can't see in the museum building today?

One of the things that the new London docks didn't have were central support columns. Without the columns, how did the roof stay up?

Activity: Divide the students into groups of three. Ask two students to link arms, straight out in front. Ask the third student to push straight down between their arms.

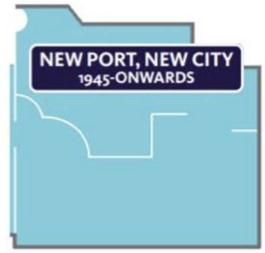
Was it easy or hard to move your friends' arms down?

Now ask two students to form their arms into an arch. Is this easier or harder to push down? Why do you think this is the case?

Activity Sheet

Full STEAM ahead!

New Port, New City gallery



Abandoned Warehousing & New Public Architecture

The warehouses became obsolete due to new technologies in the port. What sort of advancements caused the warehouses to become obsolete?

Think about transportation (better transport means less needs to be stored)

Unloading of ships became more efficient. What caused this? Look around the gallery to see some examples. (methods of packing in bulk, unloading processes such as cranes, etc)

Canary Wharf became an epicenter of creative arts due to inexpensive studio apartments. On the other side of the river, however, industry started to boom as they built up the district turning it into current Canary Wharf.

When the DLR was built they used the existing arches because they were still strong. When digging new tunnels for the underground they also used arches. Why would they design the trains and tunnels in the way they did? (for strength)

Activity Sheet

Appendix K: Testing Schedule

Testing Schedule

\\\\\\\\\\\\\\\\\\	Stinky Sewers (StS)			Ship Shapes (SS)			Packing Puzzle (P)		
Day/ T1, T2, T3	Trolley Head	Trolley Assistant, *A*	Observer	Trolley Head	Trolley Assistant, *A*	Observer	Trolley Head	Trolley Assistant, *A*	Observer
Thursday* SS, P, StS	Volunteer **	Krysta 10-11:30 Tommy 11:30-12:30	Ian	Volunteer	Ian 10-11:30 Krysta 11:30-12:30	Tommy	Volunteer	Tommy 12:30-14 Ian 14-15	Krysta
Friday StS, SS, P	Tommy	Krysta Lunch: 12-12:30	Ian *A* from 12-12:30	Krysta	Ian Lunch: 13:30-14	Tommy *A* from 13:30-14	Ian	Tommy Lunch: 15:30-16	Krysta *A* from 15:30-16
Saturday P, StS, SS	Ian	Tommy Lunch: 13:30-14	Krysta *A* from 13:30-14	Tommy	Krysta Lunch: 15:30-16	Ian *A* from 15:30-16	Krysta	Ian Lunch: 12-12:30	Tommy *A* from 12-12:30

*Lunch will be taken when not designated observer or current Trolley Assistant. When the volunteer takes lunch, both Trolley Assistants will run the activity.

**The Volunteer position will be filled by someone volunteering at the museum for the day

T1 = 10:00 - 12:30

T2 = 12:30 - 15:00

T3 = 15:00 - 17:30

Each day of testing: arrive at the museum at **09:15**, volunteer briefing at **09:30** (short explanation of what we are doing and asking them to direct families our way), setup at **09:45**, close down and clean up at **17:30**, then compare notes, discuss ideas, & update materials at **17:45**.