Developing STEM Activities for the Museum of London

An Interactive Qualifying Project

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Abstract

Our team collaborated with the Museum of London to develop STEM-based activities for children and families. We reviewed published literature about family learning in museums and observed children's programs at London museums, then designed, developed, and delivered two activities for the Easter half-term. Based on observations and participant feedback, we developed recommendations for the design and implementation of future activities. Finally, we presented the Museum of London with seven new activities based on their collections to educate children about aspects of STEM.

Executive Summary

The Museum of London is a history museum that tells the story of London from prehistory to modern times. Their mission is to educate and inspire every citizen and visitor of London from an early age. As part of the London Culture Mile, they are currently trying to incorporate opportunities for Science, Technology, Engineering, and Mathematics (STEM) education in addition to history.

The Museum of London asked our team to aid in the development of new STEM-based programs. The goal of this project was to develop, deliver, and review two STEM-based, family focused activities in order to provide recommendations for the development of future family activities, and to suggest potential STEM activities that the museum may use in the future. We divided this goal into four distinct objectives:

1. To observe programs offered by museums, with special consideration for the Museum of London, and record evidence of the Generic Learning Outcomes
2. To develop and deliver two family-oriented activities to educate children about topics within STEM
3. To summarize observations of family engagement in the activities in order to make recommendations for the design and implementation of future family-oriented museum programs
4. To develop a collection of potential future STEM activities which relate to existing exhibits and adhere to our recommendations for implementing effective activities

We began by observing interactive school sessions hosted by the Museum of London and other London museums. We observed that effective activity facilitators

- Repeated important words and concepts
- Incorporated physical motions
- Asked scaffolded questions
- Maintained an energetic, humorous, and positive attitude

Additionally, we interviewed Sandra Hedblad, the Senior Family Learning Manager at the Museum of London, and we attended the Early Years Conference, which focused on methods for engaging children under age five in museums.

We developed two STEM-based children's activities: DeTECHtives, a scavenger hunt that guides participants to find examples of the six simple machines (pulley, screw, lever, wheel and axle, ramp, and wedge) throughout the galleries, and Think Like an Engineer, an interactive demonstration about how automated vehicles must be programmed to make decisions and how engineers must consider many factors when designing a machine. We prepared worksheets, observation sheets, comment cards, and sets of instructions called Volunteer Packs for facilitating the activities.

We delivered the activities for eight days during the half-term in the museum's foyer. We recorded evidence of the five Generic Learning Outcomes: Knowledge and Understanding; Skills; Action, Behavior, and Progression; Enjoyment, Inspiration, and Creativity; and Attitudes

and Values. We also collected participant feedback in the form of comment cards. Throughout the delivery period, we modified the activities based on written and verbal feedback as well as our own observations. For example, on the first day of delivery we found that children were more interested in other activities that had a more colorful presentation, so we made a colorful sign and put it in front of our activity station to catch families' attention.

Both activities included a question-and-answer component. The DeTECHtives activity included an introduction to simple machines before the scavenger hunt, during which we encouraged children to play with simple machine toys and asked questions about the machines to help them understand their use. During Think Like an Engineer, we asked the children what a self-driving car would need to do, introducing them to the design process used by engineers. Asking a variety of questions helped children understand what engineers must do when developing new technology.

Throughout the activity delivery, we recorded evidence of the five Generic Learning Outcomes. While we noted evidence of all five outcomes for both activities, some outcomes were more prevalent than others. Knowledge and Understanding was the most commonly recorded learning outcome, while Action, Behavior, and Progression was the least commonly recorded. This was due to the activities' design, as well as our data collection process.

Feedback on the open-ended portion of the comment cards was positive in 37 out of 50 cases. Participants complimented how engaging the activities were and how we interacted with the children. Some comment cards contained constructive criticism, the most common of which was that DeTECHtives was too difficult for children five and under. We incorporated this criticism into our activities by warning families with children five or younger that the activity may be too complex for the child to complete alone.

Based on our findings from the observation sheets and comment cards, we recommend that the Museum of London incorporate the following to create successful STEM activities:

- **Clear signage:** The activity station should be colorful and well labeled to attract the attention of participants.
- **Charismatic attitude:** The facilitator of the activity should be cheerful and enthusiastic in order to maintain the participant's attention.
- **Age-appropriate variations:** The activity should take into account younger children and include simpler elements for their benefit.
- **Efficient time management:** Because the time spent with each participant is rather short, the facilitator needs to plan ahead in order to use that time efficiently.
- **Relatable topic:** Relatable topics are always very important when working with children, particularly when STEM is involved.

We used these recommendations to create a set of ideas for potential STEM-based activities that the Museum of London may use in the future. Ideas included Here to There: Transportation through History, an exploration of how vehicles and their power sources have changed over time, and Augmented Reality Activity Trails, an incorporation of Augmented Reality into our DeTECHtives activity. For each activity, we made sample Volunteer Packs with

background information, a description of the activity, intended learning outcomes, and considerations to make when delivering to different age groups.

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1 Introduction

The mission of the Museum of London is to educate and inspire every citizen and visitor of London from an early age and become a part of London's "international, educational, cultural and economic impetus" (Museum of London, Inspiring 2012). As a museum, its main roles are maintaining historical collections and providing resources for research and education. There are over one million objects in the museum's internationally renowned collections, and over 66,000 objects are accessible via Collections Online (Museum of London, Inspiring 2012). Museum education includes exhibits, on- and off-site programs, and web-based resources. Within its facilities, the museum has exhibits and research opportunities spanning all of the city's history including the Roman era, the Medieval era, and the Modern era. There are also rotating temporary exhibits on a variety of topics such as Un(Common) Currency: Currency from 18th Century to Present, Keeping Warm: 19th & 20th Century Ways to Beat the Cold, and Imagined Futures: Visions of the Future of London.

The museum engages diverse audiences and attracts thousands of visitors to its two campuses at London Wall and Docklands. In addition to permanent displays and special exhibitions, the Museum of London hosts programs designed for children and their families. These programs generally include a combination of museum group tours and hands-on activities. According to the 2017 Governor's Report, 1,085,038 visitors took part in family events and activities at the Museum of London during the 2016/17 season, surpassing the 897,508 family participants in 2015/16 as well as the museum's family attendance target for the 2016/17 season (Museum of London, 2017).

The Museum of London is part of London's Culture Mile, a group of organizations that specializes in the fusion of the creative, technical, educational, and emotional skills necessary to succeed in the twenty-first century (Culture Mile, n.d.). Science, Technology, Engineering, and Mathematics (STEM) education is crucial to this fusion. The museum's extensive collection provides the opportunity for the integration of STEM education, which will in turn increase the museum's educational scope and appeal to a wider variety of visitors.

To further their goals of educating the public, attracting visitors, and incorporating STEM, the Museum of London asked our team to design, develop, and deliver two family activities during the London Visions portion of the museum's City Now, City Future program. We designed these activities with roots in STEM concepts, and formatted them to prompt family learning and discussions. We conducted research on effective approaches to family learning, and observed family programs in several London museums. Using our knowledge of family learning and in consultation with the Museum of London staff, we developed two STEM-based activities.

The activities, which are geared towards families with children between ages five and eleven, are called DeTECHtives and Think Like an Engineer. The DeTECHtives activity teaches children how people have used simple machines throughout history. The Think Like an Engineer

activity uses the example of a self-driving car looking for an available parking space to explore how engineers program automated devices to process information. The goal is to show children that engineers design computers to use math-based logic to make decisions. We delivered both activities during the London Visions program. We repeatedly refined the design of our activities based on ongoing feedback from participants and museum volunteers and staff. We applied this feedback to compile recommendations for the design and implementation of future family activities at the Museum of London.

Upon analyzing the data gathered during our activities, we applied our findings to our ideas for potential future STEM activities. Each team member explored the galleries again, searching for exhibits and collection items with ties to STEM that could be incorporated into future activities. After sharing our ideas with each other, we compiled a list of additional STEM-based activity suggestions that the Museum of London can develop and incorporate into future programs. We outlined each suggestion in a format similar to the Volunteer Packs we wrote in preparation for our activities; the outlines include suggestions for setting up the activities, variations for different age groups, and intended learning outcomes.

2 Learning in Museums: Literature Review and Observations

In order to design well-informed family activities, the team reviewed published literature about family learning in museums and personally observed a variety of activities offered at museums in London. We reviewed studies about the characteristics of family learning, as well as different types of individual learning. To address this range of learning styles, museums offer different types of interactive activities and apply different strategies to guide discussion and prompt learning. The Museum of London itself offers hundreds of interactive activities annually (Hedblad, 2018). We share conclusions drawn from observing several such activities.

2.1 Educational Shifts in Museums

The definition of learning has evolved with advancing technology. While researchers previously viewed learning as the passive imparting of knowledge to students (Hooper-Greenhill, 1999), they now understand that learning is a process that actively involves the learner (Hooper-Greenhill, 2004; Hein, 1998). In response to the changing definitions of learning, museums have developed a more visitor-centric model of education to cater to the varying needs of their audiences. Accordingly, research concerning museum learning has shifted toward a constructivist approach that acknowledges the varying factors that can influence a family's learning experience (Bourque, Houseal, Welsh, and Wenger, 2014). Falk and Dierking developed a framework that explains how different contexts influence how visitors learn. They include three contexts in their contextual model of learning:

- Personal context: visitors' interests, prior experience, and existing knowledge
- Sociocultural context: visitors' cultural backgrounds and the way visitors interact with each other
- Physical context: location, layout, and other factors of the physical venue at which learning takes place.

All three contexts and the specific factors within them have recognized effects on learning, and thus are important to consider when examining education in museums (Falk & Dierking, 2000; Bourque et al., 2014).

Many factors influence learning, so it occurs through a variety of processes with even more different outcomes. To reflect this concept, the Research Centre for Museums and Galleries, through the Learning Impact Research Project, has created five Generic Learning Outcomes (GLOs) for archives, museums, and libraries. The GLOs are listed as (Hooper-Greenhill, 2004):

1. An increase in knowledge and understanding;
2. An increase in skills;
3. A change in attitudes or values;
4. Enjoyment, inspiration, creativity;
5. Action, behavior, progression.

These GLOs enable evaluators to identify and describe learning in museums and other cultural institutions (Hooper-Greenhill, 2004). The Museum of London is one such museum that follows this outline of GLOs; therefore, we based the analysis of our activities on observed and reported occurrences of the GLOs. Figure 1 shows a diagram of the GLOs.

A diagrammatic view
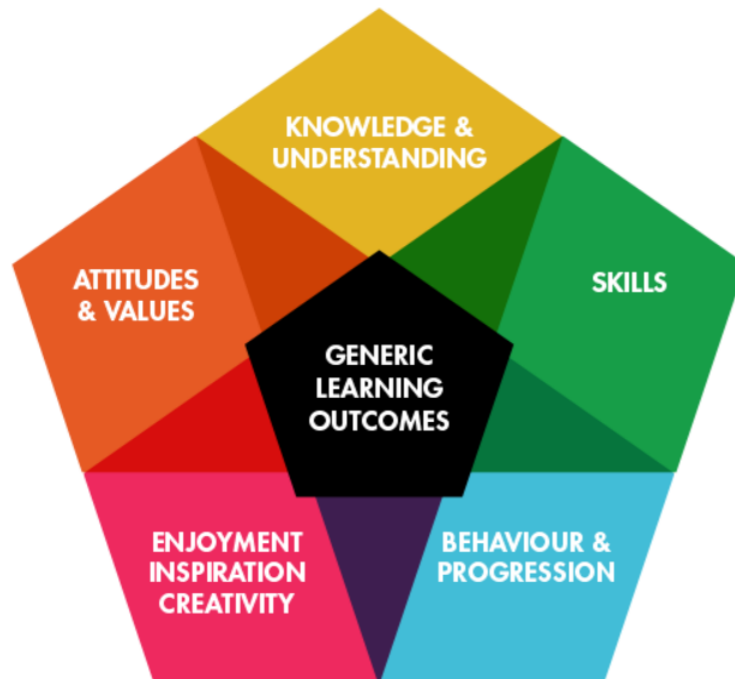
Figure 1. Diagram of the Generic Learning Outcomes (Arts Council England, Generic n.d.)

In contrast to the more formal learning present in standard academic environments like classrooms, museums use "informal" or "free-choice" learning, which is characterized by individuals having more input in their learning experience (Bourque et al., 2014). Museums spur learning by the social aspect of the experience, the entertaining quality of the exhibits and events, and the learning opportunities provided by the venue (Tenenbaum, Prior, Dowling, & Frost, 2010). Museums provide a "socially mediated" learning environment, where visitors in groups can explore individual interests and also learn about each other. For example, when parents and children have fun exploring galleries and participating in activities together, the experience becomes more memorable. Including child-oriented programs has become common practice among museums with the goal of attracting whole families. One of the Museum of London's primary strategic objectives for their five-year plan is to reach more people. The Museum hopes to increase their visitor numbers to 1.5 million visitors to their two museums each year (Museum of London, Our strategy 2012).

2.2 Family Learning in Museums

As museums have shifted from didactic to sociocultural approaches to meet the needs of their audiences, family learning in museums emerged as a distinct field of study (Briseño-Garzón, 2013). The Museum of London develops its educational activities for children and their parents using *Inspiring Learning for All: An Improvement Framework for the Arts and Culture Sector*, published by the Arts Council England. The *Inspiring Learning for All* framework identifies learning as a "process of active engagement [that] may involve the development or deepening of skills, knowledge, understanding, values, ideas, or feelings" (Arts Council England, Defining n.d.). Effective learning leads to "change, development, and a desire to learn more" (Arts Council England, Defining n.d.). Learning is a lifelong process, and a family is the first learning group to which a person belongs. Opportunities for family learning, which include showing, telling, playing, providing explanations, asking and answering questions, and reading aloud, can be found in many places, including home and nature (Briseño-Garzón, 2013). Modern museums that strive to encourage active learning and engagement can deliver activities that incorporate any number of these methods, in turn providing an optimal environment for family learning to occur.

2.3 Family Learning Findings

The PISEC study conducted by Borun et al. (1998), suggests several design considerations to improve the holding power and educational potential of exhibits. Borun and Dritsas examined several different family exhibits and determined the factors that lead to their success. The biggest takeaway from the research is to keep the exhibit simple and user friendly. In all, Borun and Dritsas identified seven characteristics of effective family learning exhibits, listed as (1997):

- multi-sided: family can cluster around exhibit;
- multi-user: interaction allows for several sets of hands (or bodies);
- accessible: comfortably used by children and adults;
- multi-outcome: observation and interaction are sufficiently complex to foster group discussion;
- multi-modal: appeals to different learning styles and levels of knowledge;
- readable: text is arranged in easily understood segments; and
- relevant: provides cognitive links to visitors' existing knowledge and experience

Active prolonged engagement allows participants to explore, observe, and investigate within the museum. According to Tenenbaum et al., participants generally spend more time and ask more questions during these activities. Finding the balance between guidance and exploration often depends on the content of the activity and requires experience to achieve (2010). However, the study also mentions the importance of exploration among the exhibits rather than a directed activity (Tenenbaum et al., 2010). A program that incorporates both independent exploration and directed activities would provide the opportunity for a robust learning experience for families.

Additionally, a successful family learning exhibit should be accessible in terms of users and size. The setup of the exhibit should accommodate both the targeted age group of children as well as adults in terms of size and ease of handling the associated materials. Several participants, especially families, should be able to cluster around an exhibit to work together and foster conversation. Exhibits that encourage multiple participants at once promote conversations and dialogue. Interaction leads to different learning experiences that increase the holding power of the interactive exhibit (Borun & Dritsas, 1997).

Researchers attempting to measure the level of engagement of an activity may choose to focus their analysis on one of several observable factors. One study conducted by the British Psychological Society tracked the word-for-word conversations that occurred between families. The study categorized conversations by topics such as exhibit-related questions, historical talk, and off-topic discussion. By recording and comparing the conversations, the study was able to determine that when given pamphlets to increase historical talk, families tended to linger at exhibits longer (Tenenbaum et al., 2010). Observing conversations between family members serves as a useful indicator of engagement in a museum activity.

A study from *Early Childhood Research Quarterly* on STEM learning in a children's museum used question-asking as a measure of learning for families with children aged around six and seven (Haden, Jant, Hoffman, Marcus, Geddes, & Gaskins, 2014). Specifically, they observed the number of "*Wh*-questions" such as "who, what, where, why, and how" (Haden et al., 2014) that the parents asked their children before, during, and after participation in a hands-on building activity. Taking into account the diverse backgrounds of the different families, they found that the activity was highly successful at dramatically increasing the number of questions that parents asked their children across the board (Haden et al., 2014). Question-based conversations indicate family learning.

Observers may also consider more general statements indicating engagement in the subject matter. A study conducted by Kaleen Povis and Kevin Crowley at a natural history museum in Pittsburgh shows another example of measuring effectiveness by listening to conversations. The authors studied an active museum program for children aged five to eight and their families and listened for examples of what they called "family-learning talk," which they defined as conversation between adults and children about the program other than just pointing out the objects on display (2015). Povis and Crowley defined learning talk broadly, ranging from questions in a similar style to those found by Haden et al., to connections to the families' personal experiences, such as "this looks like grandpa's pond" (Povis & Crowley, 2015). They found that activities designed to encourage close observation of dioramas led to greater amounts of discussion among families (Povis & Crowley, 2015).

A key contributor to conversations is a sociological phenomenon called joint attention. Children begin practicing joint attention at a young age as they learn to emulate their parents and follow their example. This behavior is often observed when children follow their parents' line of

sight and where they pay attention. When the parent finds something interesting, the child will emulate their behavior. Once the family establishes joint attention, it becomes more difficult to shift the participants' focus. However, establishing joint attention in museums can be difficult to do because of all the competing sources of attention, e.g. exhibits, activities, and displays (Povis & Crowley, 2015). When designing activities for museums, including elements to engage both adults and children can help establish joint attention on the same activity.

2.4 Activities for Different Types of Learners

By including a variety of activities in their programs, museums are also able to cater to a broader range of people that learn in different ways. The *Inspiring Learning for All* framework from the Arts Council England defines several different learning styles including kinesthetic learners, visual learners, logical learners, naturalist learners, and intrapersonal and interpersonal learners. Kinesthetic learners learn through exercising their bodies, and therefore respond well to interactive exhibits that provide opportunities for movement and handling materials. Naturalist and visual learners more clearly grasp the world around them, either through the traits of their environment or through patterns they perceive in images or data. Intrapersonal and interpersonal learners rely on introflection (either personal or group reflection) to understand new material (Arts Council England, Defining n.d.). Families are not necessarily comprised of people of the same learning type, which increases the value of multisensory museum exhibits, such as those that allow visitors to dress up, prepare food, listen to music, and draw connections between the exhibit topic and everyday life (Dierking, 2010).

Museums that incorporate activities for more than one learning style provide greater opportunity for learning, and deeper understandings for broader audiences. The Museum of London, for example, hosts programs for children and their families throughout the year. A common program format is a family walk, during which families are guided through galleries and even nearby locations to learn about a major event or era in London's history. A recent example is the *Great Fire of London Walk*, which visits galleries and locales relevant to the Great Fire of 1666 and helps children learn about its possible causes using interactive "mini challenges" (Museum of London, n.d.). Within family walks, the walking between sites can benefit kinesthetic and naturalist learners, and the discussion and activities afterwards can appeal to visual and interpersonal learners. Multifaceted museum exhibits can appeal to a variety of learning styles and age groups. Parents are more likely to bring their children to a museum that appeals to the whole family. It is important to note that in addition to different learning styles, cultural background may also affect the way families interact in museums.

2.5 Interactive Activities

Researchers generally categorize interactive activities, or activities with a social or tactile element, as either independent or facilitated activities. The latter typically include a member of museum staff who can provide directions, develop a narrative, and pose thought-provoking questions (Gelman, Maloney, & Murdy, 2017). Studies of the effectiveness of independent activities at engagement have found several important points to consider when designing family

learning programs. For example, it is necessary to ensure that the activity is simple enough for families to understand. Early versions of several activities, including a sand pendulum experiment station at the Franklin Institute, needed to be refined because visitors found the instructions difficult to understand; they often became frustrated and left the sand pendulum exhibit when the experiment had too many steps (Borun & Dristas, 1997). Instructions and printed materials must be clear, concise, and written in simple language.

When designing a facilitated activity, it is necessary to create an engaging introduction that provides a clear context for the activity. This strategy was a clear point of focus in the "Full STEAM Ahead" project sponsored by the Museum of London Docklands. The goal of the project was to design family activities that incorporated elements of Science, Technology, Engineering, Art, and Math (STEAM). Volunteers of all backgrounds facilitated the activities, using printed sheets of directions and questions designed to prompt conversation among the activity participants (Gelman et al., 2017). Another project, "Evaluating the London Science Museum's Activity Boxes at UK STEM Clubs," included a different variation of facilitated activities. Two activity boxes, "Crime Lab" and "Mars Mission," each contained an introductory film. The "Crime Lab" film, which depicted a fictional crime that the students were to solve, was well received; it introduced the activity while making students excited to participate in it. The "Mars Mission" film, in contrast, received mixed reviews because its subject matter was not as directly relevant to the activity as some of the students would have liked (Hegarty, Hitchcock, LaFleche, & Warner, 2009). It is essential that activities presented to museum-goers are clear, concise, and directly relevant to the topic at hand in order to keep participants' interests.

As discussed in the Early Years Conference (Museum of London Docklands 2018), it is important to maintain children's curiosity and creativity when facilitating an activity, as both curiosity and creativity are directly linked with learning. Creativity, through which children develop their own ideas, encourages active learning. Curiosity prompts explanation, which can lead to conversation with adults (Graham, 2018b). Conversation is a central component of early learning, as adults can help children name new objects and ideas, connect new information to previous knowledge, and develop language to express their thoughts (Graham, 2018a; Graham, 2018b). Through methods such as narrating their own thought process and asking and answering questions, adults can shape children's thinking and provide them with a model to engage with the activity themselves (Graham, 2018b). Facilitating questions can prompt discussion among activity participants as well as guide participants to understanding an activity.

2.6 Observations of Activity Facilitation

We spent the three weeks leading up to the Easter holiday observing programs of children's activities at the Museum of London and other museums. Because school was still in session, the majority of these programs were for groups of approximately 30 schoolchildren, so we focused our observations on the roles of museums staff and facilitators. One key strategy facilitators used was repetition. At the Design the Skyline workshop offered by the Tower Bridge Exhibition, the facilitator repeatedly emphasized the idea of shapes used in architecture. While

up in the tower looking at the city skyline, she asked students to draw examples they could see of cylinders, triangular pyramids, and cuboids. Next, in the classroom setting, she used the same terminology to describe the shaped blocks they used to make their own buildings. Lastly, while creating their building designs in the architecture software, she showed them how the same basic shapes, cylinder, pyramid, and cuboid, can be stacked on each other to make many building shapes. Repeating critical words throughout the course of a program helps solidify key concepts.

Another strategy is the incorporation of physical motions. In between the skits in the Pre-History puppet show session at the Museum of London, the facilitator made hand motions simulating several key actions in the show: a chipping motion to sharpen flint, a circular motion to polish smelted bronze, and the arm motion of drawing back a bow to shoot an arrow. The facilitator asked the children to mimic each motion, and gave them praise and relevant feedback (for example, "Don't hit the flint too hard, you must do it gently to get a sharp edge" or "Good job, if you pull the bow back like that your arrow will go very far"). Miming actions is good for school groups because not all the children could handle the same object at one time, but with a smaller group such as a family it is possible to achieve the same learning through physical motion while interacting with an actual physical element.

The most important strategy we observed was asking scaffolded questions, or questions that progressively guide the children's thought processes. This is notably present in the Museum of London's Hands-On workshops, in which students get to touch a variety of artifacts from the museum's collection. The facilitator of the Hands-On Romans workshop explained to us that the seven and eight-year old students participating in the activity are too young to think immediately of complex concepts like how items were used thousands of years ago, so she asked questions about the appearance and material of the items they are handling. For example, when presenting a section of a mosaic floor, the facilitator asked children to describe it: what are the textures and colors, and is it complete or broken. When asked what materials have those textures and colors, the children suggested clay and stone, which the facilitator confirmed was correct. When asked if the artifact looks like anything used today, children made the connection to tiles on the floor of a modern kitchen or bathroom. This led to the conclusion that the artifact was a broken piece of a Roman mosaic, which the children had learned about in school before their visit to the museum. Preparing questions to guide activity facilitation ensures an appropriate set of scaffolded questions to guide children to think of answers on their own.

In addition to repeating keywords, mimicking actions, and asking questions, all activity facilitators maintained enthusiasm, humor, and praise throughout their programs. The freelance artist who hosted the Fire! Fire! session about the Great Fire of London gave an excellent example of a multi-faceted activity. Her voice, gestures, and full-body movements when interacting with the children were varied, engaging and, enthusiastic. She made the experience multisensory by asking children what they thought the fire smelled like and what colors it was, asking them to make noises of what the fire might sound like as the wind spread it between buildings, and asking them to stand up and wiggle around like flames getting bigger and bigger.

She also used tongue twisters and sound effects such as silly voices and snoring to make the children laugh throughout the course of the story, and gave ample praise when they helped her mime activities such as the bucket brigade. Physical gestures, humor, and praise for good participation engages children and aids their understanding.

2.7 Programs and Exhibitions at the Museum of London

On the fifteenth of March 2018, we conducted an interview with Sandra Hedblad, the Senior Family Learning Manager at the Museum of London. Hedblad has worked for the Museum's Learning division for 14 years, and has worked on hundreds of activities. She believes that an activity should allow participants to learn something new. The Museum of London bases its definition of learning on the Generic Learning Outcomes, as discussed previously. They allow for a broader definition of learning than simply increased knowledge or development of new skills. Hedblad also discussed the importance of choosing a program topic with which participants can identify. As an example, she described a festival hosted by the Museum of London on the history of cycling. This festival included displays of different historical bicycle designs, a professional cyclist who showed children how to perform basic tricks, and a discussion of the role cycling plays in modern London life. Children and adults alike enjoyed this festival, Hedblad explained, because people are familiar with bicycles and can identify with their use.

The Museum of London has been designing family exhibits and programs for years and continues to look for new ideas. The Museum is currently nearing the end of a five-year Strategic Plan developed to guide the Museum's activities from 2013 to 2018. It contains five strategic objectives: to reach more people, to become better known, to "stretch thinking" or challenge visitors to think about major issues, to engage every schoolchild, and to stand on their own two feet financially (Museum of London, Inspiring 2012). Appendix A contains additional information about the Museum of London. In line with the goals of the Strategic Plan is City Now, City Future, a year-long series of programs and events designed to educate visitors about the evolving aspects of modern cities. City Now, City Future has utilized the vast resources within the Museum of London to develop over one hundred programs exploring different characteristics of urban life. The final phase of the season was called "London Visions," the goal of which is to "imagine the future of architecture, politics and technologies in cities and explore what London could look like in 50 or 100 years" (Museum of London, City Now, City Future 2017). The various activities, talks, and exhibits offered by the Museum of London during this program explored the ways in which the city is changing, including developments in current research, technology, environmental issues, and transportation (Murphy, 2018). The museum designs many of its programs, including London Visions, to incorporate elements of STEM that can be introduced to children (Murphy, 2018).

Though it is a history museum, the Museum of London is part of the London Culture Mile, and therefore strives to teach technical skills and educate people about STEM, both of which are crucial in the modern world. For museums and researchers, advancements in

technology are valuable in improving understanding of the past. For example, the Museum of London contains an exhibit with three-dimensional digital reconstructions of Roman structures that are now only ruins. Our activities focus on introducing children to STEM topics in both the past, as seen in museum exhibits, and the future, as imagined with self-driving cars. Children seeing these connections may become inspired and want to learn more. The use of STEM to connect history to the modern day may also help children understand and relate to items from hundreds of years ago. Educating children about STEM, the roles it has played in the past, and the roles it could take in the future serves to cultivate an interest in how the city of London could change, and how they could become involved as it does.

3 Methods

The overall goal of this project is to develop, deliver, and review two STEM-based, family-focused activities in order to provide recommendations for the development of future family activities, and to suggest potential STEM activities that the museum may use in the future. The project has four main objectives:

1. To observe programs offered by museums, with special consideration for the Museum of London, and record evidence of the Generic Learning Outcomes
2. To develop and deliver two family-oriented activities to educate children about topics within STEM
3. To summarize observations of family engagement in the activities in order to make recommendations for the design and implementation of future family-oriented museum programs
4. To develop a collection of potential future STEM activities which relate to existing exhibits and adhere to our recommendations for implementing effective activities

The team accomplished these objectives through a variety of methods including interviews, observations, and testing and revision of the activities. Figure 2 illustrates the breakdown of tasks for each objective. We delivered the two activities at the Museum of London during London Visions, which took place during the two-week Easter half-term (from the first through the fourteenth of April). We explored elements of STEM relevant to the topics of our activities and posed questions to prompt dialogue among participating families.
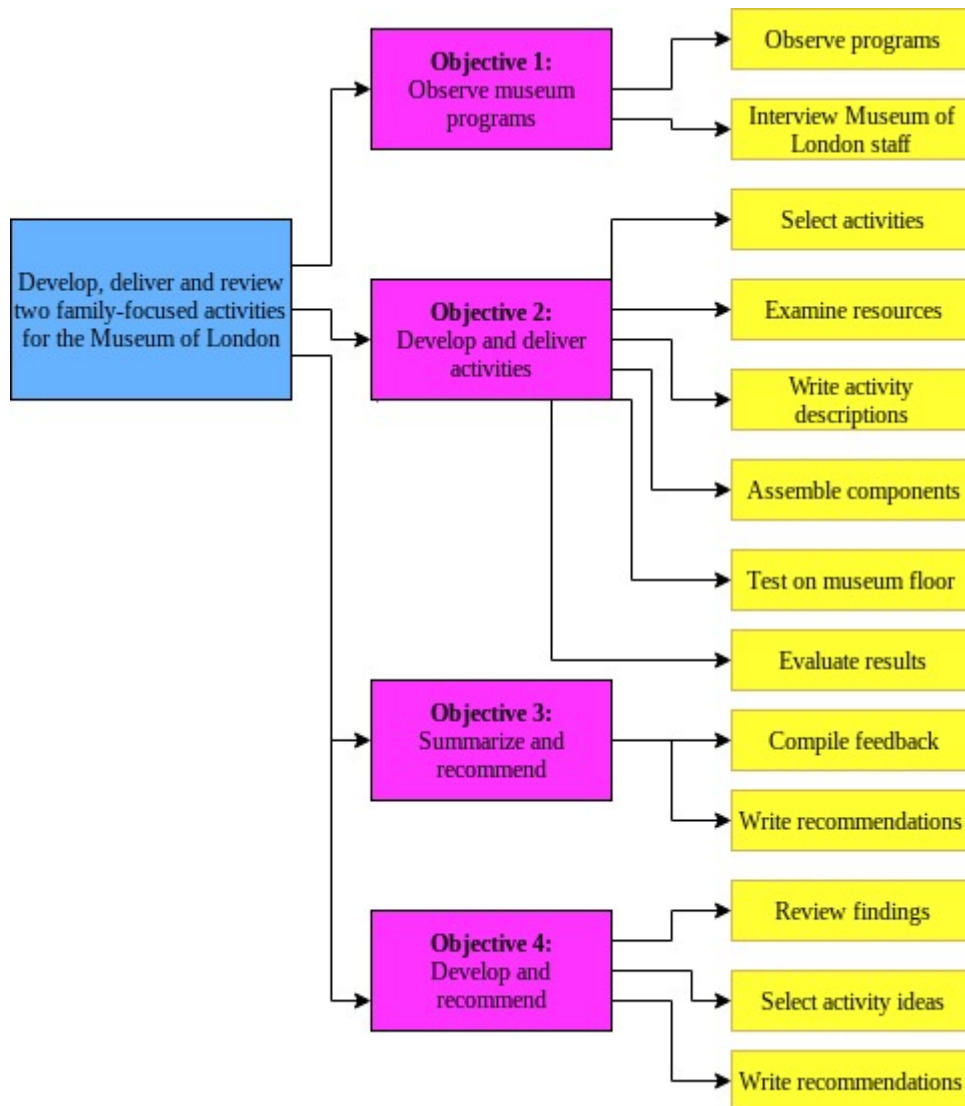
Figure 2: Diagram of goals and objectives

3.1 Objective 1: Observe Museum Programs

The first step in the project was to gain information about family programs that have been hosted by the Museum of London and other local museums, building on our review of family learning literature as described in the background chapter. We conducted an interview with Sandra Hedblad, the Senior Family Learning Manager at the Museum of London. She was a valuable resource because she has held multiple positions in the Museum of London's Learning department, and has also worked both with staff on activity development and with visitors on the museum floor. The interview, which took place in one of the break-out spaces among the Learning department offices, took approximately an hour because we had streamlined the questions to focus on Hedblad's individual experiences with different hands-on activities. There was no need to record audio or video during the interviews, as the two team members conducting the interviews took detailed minutes. Interview questions explored participant feedback and

activity presentation, features, and content. Appendix D contains the complete list of questions, as well as minutes, from the interview.

We also investigated other museums to gain additional perspective and compare different activities. Team members observed interactive programs for school groups offered by these museums to observe facilitation strategies directly. Our sponsor arranged for us to observe programs and attend conferences at the Science Museum, the Tower Bridge Exhibition, the London Transport Museum, the Victoria and Albert Museum, and Kensington Palace. Additionally, the Museum of London Docklands held an Early Years Conference, focusing on children under five, in which the team learned a great deal about incorporating younger visitors into the museum experience and creating a more integrated family activity. The team refined their own activities based on their findings. In particular, we incorporated common elements in how facilitators we observed interacted with children, and we used the concept of scaffolding from the Early Years Conference in determining questions to ask activity participants.

3.2 Objective 2: Develop and Deliver Activities

After gaining a strong understanding of the Museum of London's existing family activities and programs, we developed our own activities. These serve as the main deliverables of the project and align closely with the main goal. We developed two family activities that we delivered on the fifth, sixth, and ninth through fourteenth of April. The following sections examine activity criteria the sponsor provided us, the team's design and development process, and the delivery of the activities.

3.2.1 Design Criteria

The main requirement the sponsor emphasized is that the activities incorporate elements of STEM. The activities were available in the museum during a two-week program called London Visions, which was the culmination of the year-long City Now, City Future season. The activities offered during London Visions were tied together by a common theme: concepts that may appear in a futuristic urban setting. STEM was relevant because advancing technology will be a significant contributor to the coming years of London life. Because the program took place from the fifth through fourteenth of April, while schools were not in session, the target audience for the activities were families rather than school groups. We designed the activities so that the level of difficulty would be appropriate for children between the ages of five and eleven. We used simple language on the worksheets and in our explanations. For DeTECHtives, we chose examples in the galleries that are visible from a child's perspective, and for Think Like an Engineer, we avoided using mathematics beyond counting and basic subtraction. In order to engage adult family members as well, we included background information and guided questions to prompt discussion and further exploration.

Activity development also took the resources available at the Museum of London into consideration. Activity workspaces needed to be big enough to avoid participants feeling crowded, but small enough not to interfere with movement within galleries. To address this, we held both activities in the museum foyer, which contained plenty of space for us to set up an activity station without interfering with traffic. The sponsor had allotted a £100 budget; while the

budget was somewhat flexible, the team made a conscious effort to reuse existing museum resources whenever possible.

3.2.2 Activity Selection and Preparation

Taking into consideration the target audience and program theme, the team brainstormed more than a dozen potential activities. After voting on the ideas that seemed most feasible and fun, the team narrowed the list down to five activities to pitch to the sponsor. Appendix B includes descriptions of these five activities. The team sent the top ideas to the sponsor liaison, Olivia Murphy, who selected two of them to implement over the Easter holiday. She chose the Think Like an Engineer activity, at the time called Think Like a Computer, because it is an age-appropriate introduction to engineering concepts. It is rooted in math and computer science, but has the creative, futuristic element of self-driving cars which fit with the London Visions program for the Easter half-term. She chose the Archaeology Detectives activity for its potential to incorporate the Museum of London's new Fatberg exhibit.

The Archaeology Detectives activity asked participants to look at old artifacts as if they had recently been dug up. Rather than directly teach the participants, the activity asked them to deduce what the object was with little information, and to provide context to an artifact where one does not exist. The goal was for participants to think critically when given limited information. However, upon arrival at the museum, the team struggled to find a common theme for items to use in the activity. Concerned that the activity topic was unreasonably broad, the team considered the possibility of changing the activity, or replacing it altogether. In the interview with Sandra Hedblad, she mentioned that activity developers often select topics from the National Curriculum, thus tying in concepts that children are already learning. None of our preliminary ideas had strong ties to the museum's collection, nor were they tied to the National Curriculum. We sought ideas for a new activity in the Design and Technology section of the curriculum, and found that simple machines are a topic taught to children within our target age group. This discovery led to the development of a new activity, DeTECHtives, which focuses on examples of simple machines within the Museum of London galleries.

The DeTECHtives activity explores different uses of simple machines throughout history. Simple machines are fundamental engineering mechanisms that help to reduce the amount of force required to perform a task. Children first learn about these machines in school when they are about seven years old, which is in the middle of the age range for our activities. To begin, the activity invites participants to play with a set of toy examples of the six types of simple machines: pulley, screw, ramp, wedge, wheel and axle, and lever.

Figure 3: Simple machine toys (Amazon, n.d.)

Figure 3 includes an image of these toys. The hands-on aspect is meant to engage kinesthetic learners. After the participants become familiar with the idea that simple machines are used to make different types of work easier, the facilitator of the activity presents them with a worksheet. There are examples of all six simple machines within the museum's galleries. The worksheet contains hints for finding these examples as well as thought-provoking questions about their use and physical properties. The suggestion to discuss the questions within their group is meant to aid interpersonal learning. We designed the worksheet with very clear language and directions to follow to avoid frustration or younger participants giving up. Appendix E contains this worksheet. The DeTECHtives activity functions as a more relatable activity than Archaeology Detectives because it incorporates aspects of the children's curriculum. Because the material is familiar to them, the participants have an easier time understanding it. The information that the museum teaches is relevant to the participants as well. The DeTECHtives activity also integrates more STEM aspects than the previous activity.

The Think Like an Engineer activity uses toy cars and a simple city map, including several designated parking spots, overlaid with a grid. Figure 4 includes this map. Participants can place a car anywhere on the map and must pretend that their car, which is driving itself, needs to find the closest place to park to wait for its passenger. Children can count the grid squares from the car's position to different places on the map. The goal is to help children understand that because computers cannot "see" like humans can, they have to use math instead; a human may be able to see that a particular parking spot looks closer than another, but an automated system using GPS or Sat Nav has to calculate the distance from the current position down drivable roads to each spot to determine which is closest. The facilitator can add complexity by pointing out barriers on the two-way roads, resulting in the parking space that appears nearest actually being a longer distance away. The step-by-step process of counting grid squares and comparing distances to different parking spots may appeal to logical learners. The goal of the activity is to help children understand that engineers must take many considerations when programming an automated device.
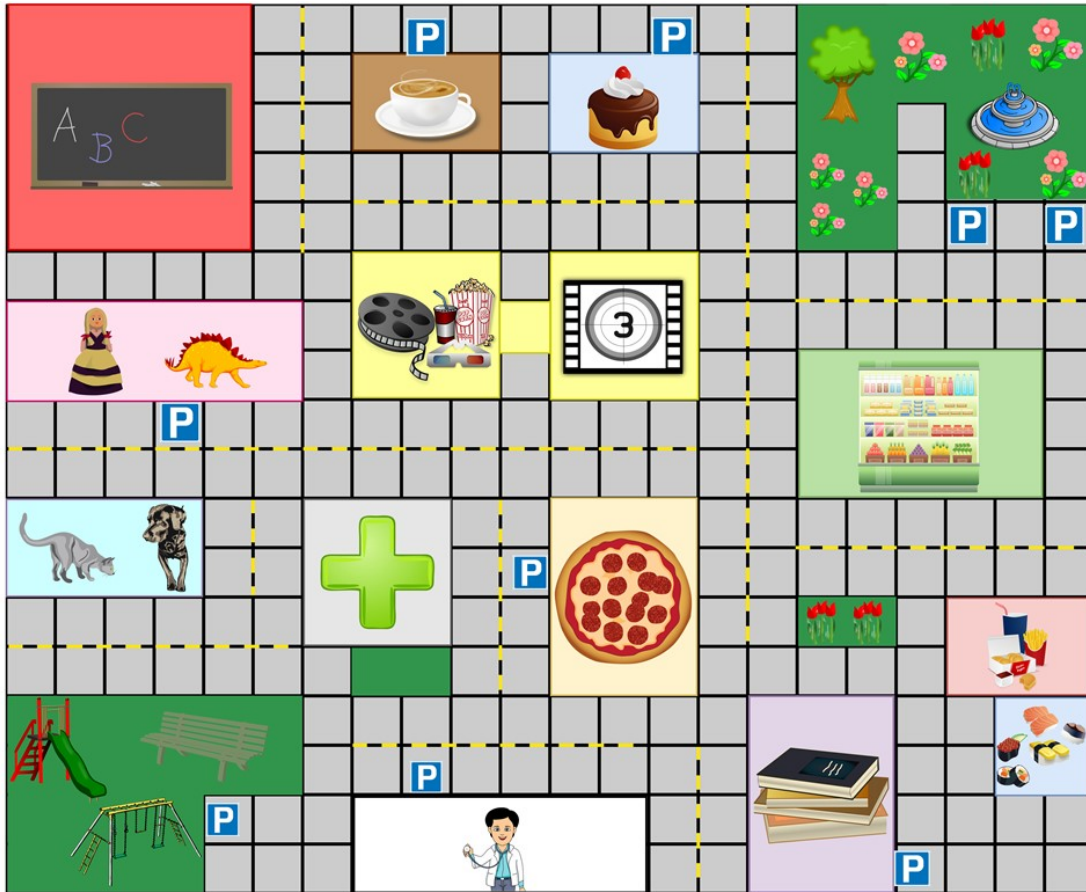
Figure 4: Think Like an Engineer map

Before bringing the activities to the museum floor, the team wrote specific instructions for the facilitation of each activity, called Volunteer Packs, so that any facilitator can present the activities in a consistent and professional manner. We also designed accompanying worksheets for each activity. The worksheet for DeTECHtives has the clues for the scavenger hunt of simple machines across galleries. The Think Like an Engineer activity has a take home sheet, where participants can draw what they think a futuristic self-driving car could look like. Appendix E contains examples of these worksheets, and Appendix F contains the text of the Volunteer Packs. The Volunteer Packs include background information, required materials, and sample questions to ask participants. They are detailed to ensure that they can be used both by museum staff as well as volunteers who may not have much experience with an activity before they facilitate it. In addition to preparing the printed materials, we also purchased a kit of simple machine examples that children can experiment with before starting their search for other simple machine examples. We made a map for Think Like an Engineer in digital design software, and ordered a print of it on a large poster.

3.2.3 Deliver and Improve Activities

We delivered the activities on eight separate days: on the fifth, sixth, and ninth through fourteenth of April. On the Thursday and Friday of the week of the first of April and the Monday through Wednesday of the following week, we facilitated the DeTECHtives activity, while on

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the subsequent Thursday through Saturday we facilitated Think Like an Engineer. We created a preamble explaining the nature and purpose of our research and placed a copy of the preamble, printed in 28 point font, at the front right corner of the display to ensure that it was easily readable for participants. The full text of the preamble is in Appendix C. Activity facilitation included scaffolded questions interspersed with facts throughout the activity, and concluded with an explanation of the worksheet. For DeTECHtives, we explained how to complete the scavenger hunt in the galleries. For Think Like an Engineer, we explained how engineers design something before they build it and challenged the children to use the engineering design strategy of perspective drawings.

At least one team member facilitated each activity delivery, and at least one other team member recorded observations. While making observations, we examined children's behavior and responses to the facilitator and looked for evidence of the five Generic Learning Outcomes. Drawing from the Arts Council England's official GLO checklist (Arts Council England, Generic n.d.), we created an observation sheet that gives checkboxes for three specific indicators of learning for each outcome, as well as a section for freehand notes. This observation sheet is in Figure 5. During each session, team members checked the box next to each indicator they witnessed. However, due to the ambiguity of which indicators applied, as well as the fast pace of the sessions, it was often difficult to check boxes during sessions. Instead, we sometimes determined which indicators to record while analyzing our written observations after the delivery period.

At the end of each session, we asked an adult from the participating family group if they would be comfortable filling out a comment card, an example of which appears in Appendix G. Between activity sessions, we analyzed the feedback on the comment cards, as well as our observations, to compile evidence of Generic Learning Outcomes, and we adjusted the activities based on verbal and written feedback. The feedback in particular was helpful in allowing us to eliminate initial design flaws. For example, after a museum staff member informed us that we had labeled one item in the DeTECHtives pamphlet with an incorrect gallery location, we corrected the label. The adjustments we made to the activity consisted of minor revisions to the pamphlet and to the verbal introduction we delivered to activity participants before they began the scavenger hunt. More significant areas for improvement, such as the DeTECHtives scavenger hunt's lack of accommodation for younger children, would have required a significant redesign of the activity for which we did not have time in between activity sessions. Instead, we addressed these concerns by warning adults with children aged five or younger that DeTECHtives may be too difficult for the child to complete alone, and that it would be beneficial to work as a team. The Recommendations section includes major improvements, such as variations based on age, that we could not complete during the week of activity deliveries.

Observer: _____

Museum of London: Activity Observations	
Activity name: _____ **Date/Time:** _____	
Knowledge and Understanding	Notes:
[ ] Learning facts or information [ ] Making sense of something [ ] Making links and relationships	
Skills	Notes:
[ ] Knowing how to do something [ ] Being able to do new things [ ] Communication skills	
Attitudes and Values	Notes:
[ ] Feelings and perceptions [ ] Increased motivation [ ] Positive attitudes in relation to an experience	
Enjoyment, Inspiration, and Creativity	Notes:
[ ] Having fun [ ] Creativity [ ] Exploration and experimentation	
Action, Behavior, and Progression	Notes:
[ ] Change in behavior [ ] Progression towards further learning [ ] Reported or observed actions	

Figure 5: Activity observation sheet

3.3 Objective 3: Summarize and Recommend

The team offered the activities within the museum during the London Visions program. We based evaluation of the activities on observation and participant feedback, gathered from observation sheets and comment cards, respectively. We based group findings on which elements of the activity prompted positive feedback and family conversation. The team also looked for

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evidence of learning outcomes, using the five GLOs outlined by the Arts Council England to evaluate the educational quality of the activity (Generic n.d.). We kept track of indicators of the five GLOs during these observations, as Figure 5 shows. These indicators also come from the Arts Council England (Generic n.d.).

Our team used the feedback and observations we collected to determine what elements contribute to an engaging STEM activity. After summarizing what we learned from the development and delivery of the activities, we applied knowledge gained from the literature review and observations of other museums to make suggestions for the development of interactive activities that the Museum of London may offer in the future.

3.4 Objective 4: Develop Future Activity Suggestions

After analyzing the data collected during activity delivery, the team considered our findings, as well as existing Museum of London galleries and exhibits, and developed a collection of ideas for future STEM-based activities. Individually, each team member explored the galleries looking for exhibits and collection items with connections to STEM, and brainstormed ways to incorporate them into activities for children. The team then collaborated to choose the most feasible ideas. We were able to design seven ideas with sufficient detail to present as formal recommendations. The activities address a broad range of topics and take forms including worksheets, performances, and crafts in order to appeal to a wide audience with different interests and learning styles. Appendix H contains the full list of our recommendations, in the form of activity descriptions. Each description includes a working title, necessary background information, a description of the activity procedure, intended learning outcomes, and features of the activity to incorporate for younger audiences.

4 Findings

We presented and facilitated our activities for eight days at the Museum of London; we noted evidence of Generic Learning Outcomes on printed observation sheets, collected feedback from adult family members in the form of comment cards, and revised our facilitation techniques as we gained practice interacting with children and their families. Our findings are grouped in four main categories: the outward presentation of the activity, the techniques used when interacting with participants, the observed and reported evidence of Generic Learning Outcomes, and the comparison between the two activities. These findings provide insight into which aspects of an activity engage participants, as well as which elements successfully express STEM concepts to children.

4.1 Outward Presentation

During delivery, we altered some aspects of the activities in order to increase the number of visitors that stopped at the activity station. During the first iteration of the DeTECHtives activity, many younger children glanced at our table, but instead chose to approach the Future London craft activity in a different area of the foyer. The more colorful and creative aspects of that activity attracted more attention from families, so we incorporated more colors and eye-catchers into our display. We laid out a set of colorful simple machine toys on our table, but noticed that families did not approach even after looking inquisitively at the display. Before delivering DeTECHtives the next day, we made a sign on a standing chalkboard in brightly colored chalk markers to put next to the activity station. This attracted noticeably more participants, because upon reading the sign, many parents asked "Do you want to do a scavenger hunt?" or "Do you want to be a DeTECHtive?" and children were interested enough to approach. We repeated this approach for the Think Like an Engineer activity, and made a similar sign. Figure 6 includes the signs for both activities.
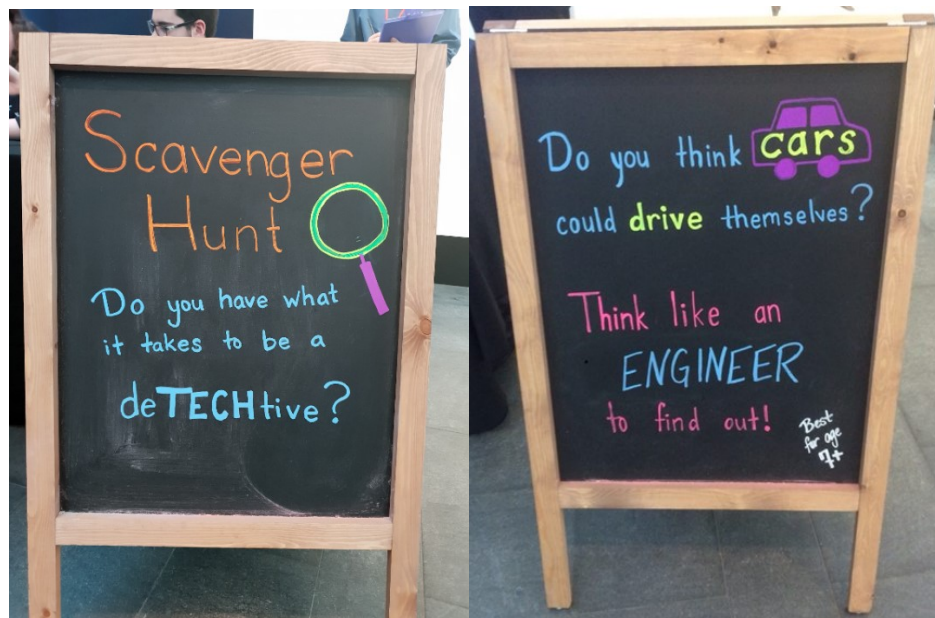

Figure 6: Chalkboard signs for DeTECHtives (left) and Think Like an Engineer (right)

The addition of the large sign was a better choice than moving to a location outside the foyer to avoid the craft activities. The foyer was a good location for the DeTECHtives activity because it allowed us to introduce the activity and distribute the scavenger hunt sheets when families arrived at the museum, and allowed them to stop by and show us their filled-in sheets and receive their reward stickers before they left. When the families returned to the station together at the end of their visits, we asked one adult in the group if they were comfortable providing feedback on a comment card while we gave the children their stickers. The foyer was the most reasonable location for the Think Like an Engineer activity as well, since that activity was not directly related to any of the museum's galleries.

Because we set up our activities in the foyer, we began to notice distinct ebb and flow in the arrival of museum visitors. During the lulls in visitors just after opening time and during the lunch hour, we had the opportunity to speak to other museum staff. The Museum of London has a team of staff members called the Host team, and in addition to being positioned throughout the galleries to provide guidance to visitors, there are always several Host team members stationed in the foyer. They welcome visitors that come through the door, and give information about the layout of the museum and about any special activities happening that day. We gave basic details about our activities to the members of the Host team stationed in the foyer, and they informed families with children in the target age range about the activities and pointed them towards our station. By collaborating with the Host team, we were able to interact with even more families, and make a strong first impression before families entered the galleries.

Our initial choice of activity location was successful, but choosing times to offer the activities was more difficult. We began our first iteration of DeTECHtives in the early afternoon, but realized that many of the families we saw were leaving the museum and fewer were arriving. We began the next session earlier, and got noticeably more participants as they entered the museum for the day. Beginning either activity between 10:00 and 11:00 in the morning allowed us to interact with many of the visitors who arrived within an hour of the museum opening. For the DeTECHtives activity in particular, this choice of starting time also allowed families to go through the museum at their own pace while still being able to claim their prize stickers in the afternoon, before the activity ended for the day.

4.2 Interaction with Participants

After introducing the DeTECHtives activity to the first few families, we developed a consistent facilitation format based on what we found to be the most engaging. We began with demonstrations using the simple machine toys, and whenever possible we encouraged children to play with them. Younger children in particular enjoyed this play aspect, and it appeared to make them excited about the scavenger hunt portion of the activity. In order to keep participants' interest and also be able to provide information to all the groups that came to the table, each family's time at the activity station was only a few minutes long. This was often not enough time to explore all six simple machines, so the activity facilitators focused on introducing the lever and the pulley, as they are both simple machines that aid lifting. We used the demonstration of the lever and pulley to introduce the scavenger hunt, and explained that simple machines have

been used throughout history to make work easier. We then outlined how to do the scavenger hunt through the galleries, explained that there was a reward "Trainee Engineer" sticker for children who returned with filled out worksheets, and sent the participants off on the challenge. Figure 7 provides an image of this sticker, and one comment card even declared "Loved the stickers!"

Figure 7: "Trainee Engineer" sticker

The DeTECHtives simple machine demonstration, the setup of which appears in Figure 8, allowed children to experiment with the simple machine toys while also answering scaffolded questions to guide their understanding of the activity's theme. After being asked to pull the string on the pulley, we asked "if you had to lift something really heavy, would you rather use a pulley like this, or just lift it up with your hands?" Children almost always responded with the pulley, indicating that they understood how the mechanism is useful. For the lever, the questions focused more on connecting to personal experiences, for example "does this remind you of anything you've seen before?" and if they seemed hesitant, "perhaps on a playground?" The child often answered that the model lever looked like a seesaw. This clear personal connection served as evidence of the Knowledge and Understanding learning outcome; many children knew what happened when they shared a seesaw with a sibling, as well as what differed when they share it with an adult instead.

Figure 8: DeTECHtives setup

During our second iteration of the DeTECHtives activity, we began asking the ages of children who approached the table. We based this practice on feedback from a comment card that stated that the worksheet was too difficult for a five-year-old. Asking about ages served multiple

benefits; for groups with one or more children under age five, it allowed us to politely inform the parents that the activity was likely too advanced. For children around ages six to ten, it was an ice breaker to encourage them to talk to us. For groups that included a range of ages, it provided an opportunity to suggest to the group that they work as a team, with young children working with older siblings or parents. Knowing the child's age beforehand also allowed us to adjust the pace of the demonstration and the level of detail provided in the explanations to accommodate their level of understanding. Asking the age of the child also helped us to tailor the activity based on commonalities we found in certain age groups, and thus foster more reliable recommendations for future activities.

After five sessions of the DeTECHtives activity, we gained a better understanding of the attention span and abilities of differently aged children. Given this, we realized that the Think Like an Engineer activity included too much technical language for most five and six year old children, so we included a "Best for ages 7+" notice on the chalkboard sign. This way, we were able to attract mainly families with children who would be able to get the most out of the activity.

We divided the Think Like an Engineer activity facilitation into two parts, both about considerations that engineers must make when developing a piece of technology. First, the facilitator asked the children how long they thought it would be before they could look out the window and find that many of the cars they saw on the road were not being driven by people. After hearing their answers, we explained that it is estimated that self-driving, or automated cars will be available on a consumer level in as few as ten to twenty years. We explained that scientists and engineers are currently working to make self-driving cars that can operate safely in areas like cities that have lots of people, but that there are many constraints an engineer must consider. Given the example of cars, we asked the children what actions cars must be able to do, receiving answers like drive, steer, and park or stop. At this point we turned focus to the large printout of the map in Figure 4 and invited the children to pick a toy car and place it on the road near a shop or location they wanted to go. We posed the scenario "Pretend this is the future, and your car has just dropped you off at (chosen location) and now it must find a place to park itself and wait until you are ready to be picked up. Which available parking space on the map is closest?" They would point to a space, and we would ask how they knew. Some children made the connection to the grid squares on the map, while others were confused. We explained that humans can judge distance with their eyes, but computers do not have eyes, so engineers must program them to make decisions using other information. We used the example of Sat Nav to explain the idea of coordinates, or numbers that a computer uses to determine where objects are in relation to each other. We explained that the computer driving the car could subtract the distances to nearby parking spots to determine which is closest, and therefore where the car should park. The facilitator asked the children to count the distances to parking spots for each of their cars. For older children, we added complexity by pointing out barriers down the center of two-way roads that could not be crossed, and in some cases, the distance added by going around

the barrier made another parking space the nearest option. The conclusion was that engineers have to consider many possibilities when programming a computer to do something.

The second portion of the activity focused on the take-home sheet, which Appendix E includes. We began by explaining that before building anything, engineers must consider what the product will look like, and to do so they create perspective drawings, or pictures of the product from different points of view as seen in the sample on the worksheet. The facilitator challenged children to draw what they think a car from the future will look like, but do it as an engineer would; for example, if their car would have wheels or a hovering mechanism, that should be drawn on the bottom view, and if the car would have headlights, they should be visible on the front. During the final day of the activity, a parent suggested using one of the toy cars from the map part of the activity to help explain perspectives, which we incorporated in the rest of the day's sessions. We concluded the activity by giving each child a "Trainee Engineer" sticker, praising them for "all their hard work thinking like engineers."

4.3 Evidence of Generic Learning Outcomes

As we discussed in the Methods section, we formatted the observation sheets and the comment cards to look for evidence of the five Generic Learning Outcomes: Knowledge and Understanding; Skills; Attitudes and Values; Enjoyment, Creativity, and Inspiration; and Action, Behavior, and Progression. The precise occurrence of each GLO was difficult to measure for multiple reasons. Due to the brief period of time during which a particular family visited our activity station, it was impossible to record every action, and often, the outcomes that related to a specific observation were open to interpretation. However, the checkbox format of the observation sheets and the questions on the comment cards allowed us to record indicators of each GLO, and estimate how often evidence of each one appeared. For the DeTECHtives activity, we recorded observations of 172 family groups, and received feedback from 62 comment cards. For the Think Like an Engineer activity, we recorded observations from 37 family groups, and received feedback from 34 comment cards. Using both our observations and the reported responses to comment cards, we found that participants in both activities consistently exhibited evidence of all five GLOs, although some indicators were more common than others.

On the observation sheets, we defined each Generic Learning Outcome by three observable indicators. For each GLO, we include a table which shows the number of times we reported each indicator and the percentage of participants who displayed the indicator out of the total number of observed participants. The table also includes the total number of participants for whom we recorded at least one indicator of that learning outcome, and the percentage of participants who showed some sign of the learning outcome.

The comment card categories asking participants to rank their experience reflected the same five GLOs. For the DeTECHtives activity, the responding adults indicated strong agreement with all the statements. The responses for Think Like an Engineer were more mixed, but still mostly positive. While this may indicate that families consistently enjoyed the activities and learned from them, there are at least two factors that likely bias the results toward agreement.

One is that adults would sometimes simply circle "5" under each statement on the card, and leave either no additional comment or only simple statements such as "good job." These adults may not have read the questions or fully considered their experiences with the activity. Another factor is the nature of the DeTECHtives activity's design. We asked the adult members of the family to fill out the comment card only after they returned to the station after the scavenger hunt, not during the introduction. Families with children who did not enjoy the activity would sometimes not return. The fact that there was a higher number of observed family groups than comment cards, as well as the fact that the results for Think Like an Engineer were not as strongly skewed, indicate this. As a result, we can only use the comment card data to draw conclusions about families who returned to the activity station after the DeTECHtives scavenger hunt.

4.3.1 Knowledge and Understanding

The most frequently noted Generic Learning Outcome in our observations was Knowledge and Understanding. The three indicators of this outcome are learning facts or information, making sense of something, and making links and relationships. Approximately 84.9% of participants in DeTECHtives and 94.6% of participants in Think Like an Engineer showed at least one indicator of this outcome. Exactly what constitutes evidence of this outcome is subjective, but there is evidence that many children did learn from our introduction. For example, the majority of participants were able to answer the facilitator's questions correctly, which suggests that they understood the material being presented. Behaviors such as answering questions and paying attention to the facilitator's introduction were not only common but easy to notice, which was likely the reason we observed Knowledge and Understanding more than other outcomes.

DeTECHtives (172 participants observed)	Learning facts or information	Making sense of something	Making links and relationships
# times reported	79	84	114
% reported out of total possible	46%	49%	66%
# of participants that displayed at least one indicator			146
% of participants who demonstrated outcome			84.9%

| TLaE (37 participants observed)	Learning facts or information	Making sense of something	Making links and relationships
# times reported	20	22	20
% reported out of total possible	54%	59%	54%
# of participants that displayed at least one indicator			35
% of participants who demonstrated outcome			94.6%

Table 1. Knowledge and Understanding data for both activities

Arguably more significant than the outcome's prevalence, however, is its most frequently noted subcategory, making links and relationships, as seen in the DeTECHtives portion of Table 1. Throughout the delivery of DeTECHtives, we found that scaffolding questions which connected the material with participants' everyday lives encouraged active participation and engagement with the material. When we asked if the toy lever reminded children of anything they had seen before, most of them answered "seesaw," and often, when we asked if children had ever ridden a seesaw with someone much larger, accompanying adults would laugh and say that they had been the larger person. Although some children didn't recognize the seesaw as a lever, this connection seemed to aid in understanding. Connections in the Think Like an Engineer activity came from children's knowledge of cars and Sat Nav systems. We asked children to think about what a self-driving car needs to be able to do, and they thought of ideas with their adults. They usually said that the car must know how to turn, when to stop, and where to go. This led to the Sat Nav connection; the children now knew that we already have technology to give directions. The children appeared to make more sense of the activity after they made the connections. The Think Like an Engineer portion of Table 1 shows that the subcategory making sense of something was most prevalent in that activity.
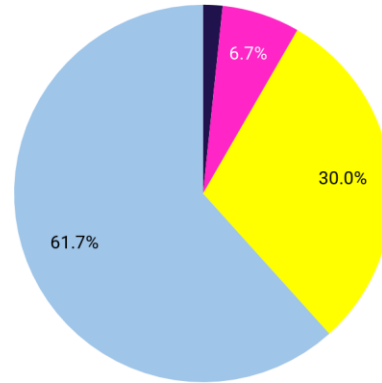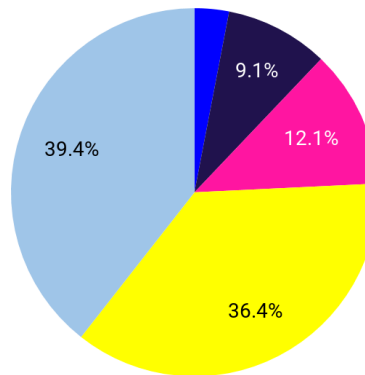
Figure 9: Knowledge and Understanding comment card data

The statement on the comment card "I discovered some new information" indicated the adult's perception of Knowledge and Understanding from their children. Figure 9 shows the distribution of the five levels of agreement of this statement for both activities. Over 90% of responders expressed agreement with the statement for the DeTECHtives activity, and under 2% expressed disagreement. This indicates that the adults in families who completed the activity believed their children learned something new, although this does not take the previously mentioned biases into account. The data for the Think Like an Engineer activity was similar but less skewed. For this activity, just over 75% of responders expressed agreement and about 12% expressed disagreement. This more clearly indicates that adults believed that their children understood the activity and learned from it, because no one had to return to the station to fill out the comment card.

4.3.2 Skills

Evidence of Skills during the activities was not as prevalent as evidence of Knowledge and Understanding. The observable indicators of Skills are knowing how to do something, being able to do new things, and communication skills. About 65.1% of observed participants for DeTECHtives and about 86.5% of observed participants for Think Like an Engineer exhibited one or more indicators of Skills. This is partly due to the nature of the activities. In

DeTECHtives, children did not interact with the simple machine toys for more than a few seconds, and these toys do not require skills beyond pulling a string, putting objects on a lever, and pushing a cart. In Think Like an Engineer, children did not need to use many skills beyond counting grid squares.

DeTECHtives (172 participants observed)	Knowing how to do something	Being able to do new things	Communication skills
# times reported	28	12	98
% reported out of total possible	16%	7%	60%
# of participants that displayed at least one indicator			112
% of participants who demonstrated outcome			65.1%

TLaE (37 participants observed)	Knowing how to do something	Being able to do new things	Communication skills
# times reported	27	8	18
% reported out of total possible	73%	22%	49%
# of participants that displayed at least one indicator			32
% of participants who demonstrated outcome			86.5%

Table 2. Skills data for both activities

Table 2 shows that the most common indicators for Skills were communication skills and knowing how to do something. This was true for both activities. Communication skills were prevalent in DeTECHtives because of the question-and-answer aspect of the initial demonstration. When we asked what happens when they pull the string, many children answered that "it goes up," referring to the weight. The response was often loud and immediate. This behavior shows evidence of confidence in their knowledge and strong communication skills. Some other children, especially those younger than seven years old, were shy and hesitant to answer questions at first. In these cases we saw the benefits of scaffolded questions. Usually, once a quieter child began to play with the pulley, they felt more comfortable describing what happened and deciding if they would rather lift a heavy object with or without the pulley. This trend generally continued when we moved on to the lever, usually after they made the connection to a seesaw. When we asked what happens when a child is on one end of the seesaw and an adult is on the other end, they correctly answered that the child stays up in the air and the adult remains on the ground. The personal connection, and by extent better understanding, led to a more confident response to the question. This served as evidence of communication skills development. The Think Like an Engineer activity involved a similar question-and-answer component. We often began by asking the children how many years they thought it would take before cars would be able to drive themselves. Younger children were hesitant to answer this

question, indicating that they may have found it challenging. However, simpler questions such as "which parking spot is closest to your car?" were easier for children of all age groups to understand. They often answered this question nonverbally by pointing to the square on the map.

During our observations, we also noted conversations that adults had with their children as we facilitated the activity. Usually for the shyer children the adults simply reiterated the same question we posed to the child in a comforting tone. This behavior demonstrates the adults' attention to the activity and their willingness to help their child learn. Sometimes the adult gave hints to the child to help them answer our questions. These hints often came in the form of reminders about previous times the family had played or spent time together. The connections that the adults pointed out to their children also helped to strengthen the learning from our activity. Additionally, adults often encouraged their children to participate and interact with our activity more. This became particularly helpful for children with short attention spans, as well as with the more hesitant participants. The parents helped the children learn by encouraging them to interact and think about the activity to a greater degree. After the Think Like an Engineer activity one parent remarked to her son "Maybe you could make a car for me in the future!" showing the progression towards further learning and how parents motivated their children to learn from our activities.

The aspects of the interaction with the children that qualify as knowing how to do something, the other most common indicator of Skills, is more subjective. As we stated previously, physical actions in this activity are basic; most children are expected to know how to perform any actions with the provided toys. Thus, we were not always consistent in determining what action counted as knowing how to do something. Some known actions we observed during DeTECHtives include understanding to pull the string on the pulley, and how to add weight to either side of the lever. The most common skill we recorded for Think Like an Engineer was successfully counting grid squares to parking spaces. Table 2 demonstrates that a majority of the participants learned how to count squares to determine the closest parking space.

DeTECHtives

- ● Strongly Disagree
- ● Neutral
- ● Agree
- ● Strongly Agree

15.0%

55.0%

26.7%
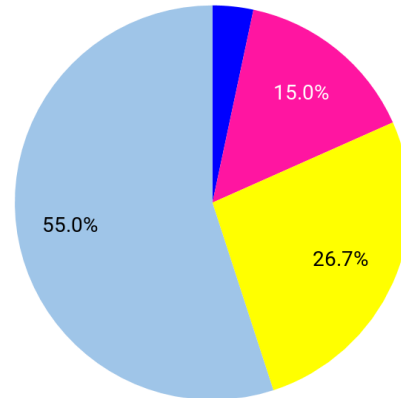
Think Like an Engineer

- ● Strongly Disagree
- ● Disagree
- ● Neutral
- ● Agree
- ● Strongly Agree
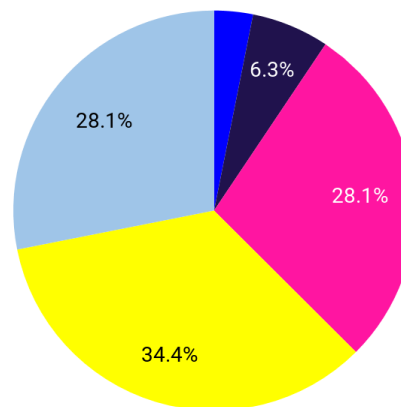
6.3%

28.1%

28.1%

34.4%

Figure 10: Skills comment card data

The statement on the comment card "I learned how to do some new things" indicated the adults' perception of Skills from their children. Figure 10 shows the distribution of the five levels of agreement to this statement based on both activities. For DeTECHtives, just under 82% of responders expressed agreement with the statement, while about 3% expressed disagreement. For Think Like an Engineer, 62.5% expressed agreement while 9.4% expressed disagreement. The rate of agreement is slightly lower than that for the Knowledge and Understanding question, suggesting that a slightly lower number of adults believed their children acquired new skills than learned new facts. While it is difficult to know this fact for certain based on a relatively small sample size, it is true that the DeTECHtives activity focused more on new information than skills. The worksheet consists mainly of definitions of simple machines, vocabulary words, and questions encouraging learning from the displays in the galleries; it does not explicitly state any new skills children can gain from the activity. It is possible, therefore, that the lower number of

adults who noted that their child had "learned how to do some new things" was simply a byproduct of the activity's design.

The difference between the Knowledge and Understanding and Skills responses was more prevalent in the comment cards for Think Like an Engineer. About 62.5% of responders expressed agreement with the Skills statement, as opposed to just over 75% for the Knowledge and Understanding statement. As with DeTECHtives, this may be due to the activity's design; Think Like an Engineer did not require many skills beyond counting grid squares.

4.3.3 Attitudes and Values

Attitudes and Values only included 49.4% of observed participants from the DeTECHtives activity and 51.4% of observed participants for the Think Like an Engineer activity, making it the second least observed learning outcome for both activities. This is partly because the indicators, including feelings and perceptions, increased motivation, and positive attitudes in relation to an experience, are all subjective and difficult to observe. However, we noted some observable indicators. For example, an observer could interpret a smile on a child's face as positive feelings or an enthusiastic attitude. Despite this, it was still difficult to determine which behaviors indicate Attitudes and Values as a learning outcome.

DeTECHtives (172 participants observed)	Feelings and perceptions	Increased motivation	Positive attitudes in relation to experience
# times reported	29	51	42
% reported out of total possible	17%	30%	24%
# of participants that displayed at least one indicator			85
% of participants who demonstrated outcome			49.4%

TLaE (37 participants observed)	Feelings and perceptions	Increased motivation	Positive attitudes in relation to experience
# times reported	5	11	7
% reported out of total possible	14%	30%	19%
# of participants that displayed at least one indicator			19
% of participants who demonstrated outcome			51.4%

Table 3. Attitudes and Values data for both activities

Table 3 shows that for both activities, the most commonly observed indicator of the Attitudes and Values outcome was increased motivation. Some children saw the sign that said "Scavenger hunt" or "Think like an Engineer," and the toy simple machines or cars on the table, and immediately expressed interest in trying our activity. Others had to be persuaded by the adults with them. Even if they were initially hesitant, the children often became more invested in

the activity once they got the chance to play with the toys. The biggest increases in motivation during DeTECHtives came when the facilitator showed them the scavenger hunt sheet and explained that they could earn a sticker if they completed the activity. At this point, the participant would usually say they wanted to give the scavenger hunt a try, representing an increase in motivation. When the child's family returned to get their sticker, they showed the facilitators their filled-in worksheet. Interest in the Think Like an Engineer activity mostly came from the interactive component. Children became more excited when they got the chance to play with the toy cars instead of answering questions in the beginning. They also expressed interest in designing a self-driving car on the worksheet. As section 2.5 states, these behaviors indicate the child's excitement and engagement.
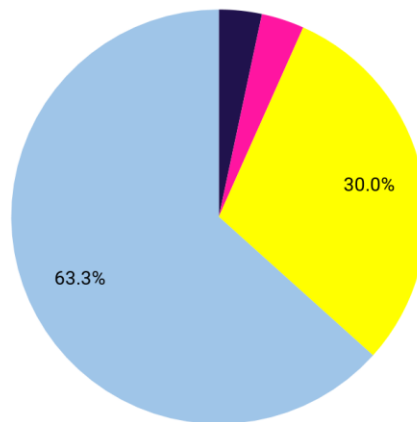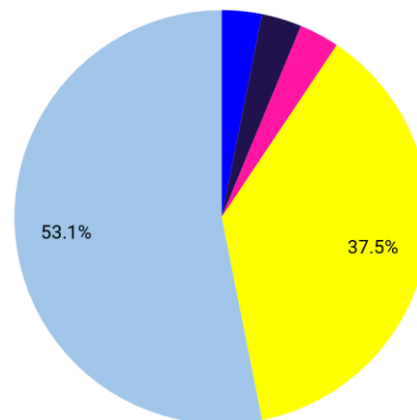
Figure 11: Attitudes and Values comment card data

On the comment cards, the statement that corresponded to Attitudes and Values was "This activity helped me see that museums can be fun." Figure 11 shows the distribution of the five levels of agreement to this statement for both activities. Both the DeTECHtives and Think Like an Engineer activities obtained a high level of agreement to this statement; about 93% of responders expressed agreement for DeTECHtives, and about 91% of responders expressed

agreement for Think Like an Engineer. This indicates that families enjoyed the activity, and that the activity had a positive effect on their impression of the Museum of London. We can make this conclusion because the results are consistent between the two activities.

4.3.4 Enjoyment, Creativity, and Inspiration

The Enjoyment, Creativity, and Inspiration outcome was the third most prevalent outcome for both activities. About 52.3% of observed participants in DeTECHtives and about 62.1% of observed participants in Think Like an Engineer exhibited evidence of this GLO. Table 4 shows that of the three indicators for this outcome, the most commonly noted in both activities was exploration and experimentation. For DeTECHtives, nearly all exploration and experimentation observations related to the simple machine toys we placed on the table; many children explored the simple machines beyond our demonstrations of the pulley and lever. For example, there were several instances in which, after watching our demonstration of the lever, a child experimented with plastic weights and attempted to balance it. In particular, the younger visitors that approached the station were the ones most excited to explore the set-up of the simple machines. The children aged five or younger were fascinated with the colorful toys and often began playing with them before any facilitator began to speak. This playtime is an example of learning through exploration, which, according to the Early Years Conference, is the primary means of learning for children of that age (Graham, 2018). For Think Like an Engineer, children played by driving their cars along the roads to different buildings, and pretending to park the cars when they were done. They also experimented when trying to find the parking space closest to their car on the map. Section 4.3.2 discussed this already; this was used as an indicator for Skills.

DeTECHtives (172 participants observed)	Having fun	Creativity	Exploration and experimentation
# times reported	46	9	71
% reported out of total possible	27%	5%	41%
# of participants that displayed at least one indicator			90
% of participants who demonstrated outcome			52.3%

TLaE (37 participants observed)	Having fun	Creativity	Exploration and experimentation
# times reported	15	3	16
% reported out of total possible	41%	8.1%	43%
# of participants that displayed at least one indicator			23
% of participants who demonstrated outcome			62.1%

Table 4. Enjoyment, Creativity, and Inspiration data for both activities

Table 4 shows that the other most common subcategory for this GLO was having fun. Again, this was the case for both activities. Fun and enjoyment is difficult to measure, as we cannot definitively indicate enjoyment through observation alone. However, by looking for physical indicators such as smiles and laughter, we were able to record instances of having fun. Further evidence that families enjoyed themselves came from the comment cards and conversations with families after they had completed the scavenger hunt. When we asked children if they had enjoyed themselves, they often replied that they had. Adults often reported that their children enjoyed the activity as well. One comment card states "It was really fun and [we] learned a lot!"
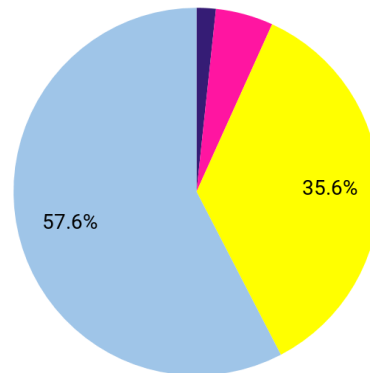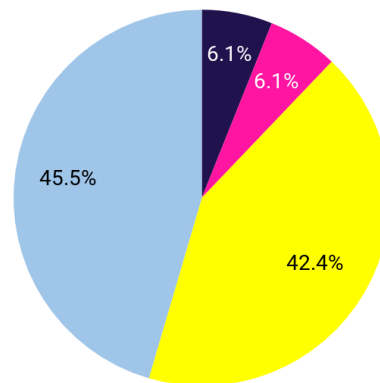
Figure 12: Enjoyment, Creativity, and Inspiration comment card data

On the comment cards, the corresponding statement to this GLO was "This activity was interesting and engaging." Figure 12 shows the distribution of the five levels of agreement to this statement for both activities. For DeTECHtives, over 90% of respondents expressed agreement with this statement, while under 2% expressed disagreement. While this may suggest that participants overall found DeTECHtives enjoyable, it is important to note that not every participant filled out a comment card. Since we only asked adult participants to fill out a comment card after they had attempted the activity and returned to the table, our sample of comment cards only comes from participants who chose to return. Most of these participants

found the activity interesting enough to at least make an attempt, which skewed the data toward more positive results.

A larger percentage of participants filled out comment cards for Think Like an Engineer, likely because it did not require a second visit to the station. About 88% of respondents agreed with "This activity was interesting and engaging," while about 6% disagreed. Though it is important to note the results' accuracy is subject to the factors the introduction to section 4.3 lists, the results suggest that participants overall enjoyed the activity. Several positive comments on the cards support this claim; one, for example, said "It was very interesting and interactive. My son really got involved. Good job!"

4.3.5 Action, Behavior, and Progression

Action, Behavior, and Progression was the least commonly observed learning outcome for both activities. Its indicators are change in behavior, progression towards further learning, and reported or observed actions. Only about 44.2% of observed participants for DeTECHtives and about 37.8% of observed participants for Think Like an Engineer exhibited evidence of this outcome. This trend is likely because it was the most subjective learning outcome. This pattern remains the case even taking into account the comment cards; the only quantitative measure of this outcome contained in the cards is the statement "I would like to come to the Museum of London again and do more activities," which may be true for a variety of reasons, including reasons unrelated to our activity. However, we did receive feedback on comment cards that indicated a desire to return, such as "We had a really interesting day, can't wait to come back."

DeTECHtives (172 participants observed)	Change in behavior	Progression towards further learning	Reported or observed action
# times reported	18	59	14
% reported out of total possible	10%	34%	8%
# of participants that displayed at least one indicator			76
% of participants who demonstrated outcome			44.2%

TLaE (37 participants observed)	Change in behavior	Progression towards further learning	Reported or observed action
# times reported	3	10	3
% reported out of total possible	8%	27%	8%
# of participants that displayed at least one indicator			14
% of participants who demonstrated outcome			37.8%

Table 5. Action, Behavior, and Progression data for both activities

Table 5 illustrates that for both activities, the most frequently noted subcategory of this learning outcome in the observation sheets was progression towards further learning, which we defined as likelihood that a child will continue to learn about the subject of the activity after completing it. Unfortunately, we could not effectively measure progression towards further learning before the activity was complete. However, we did find the potential for future learning in many interactions with returning families. When families returned with completed worksheets during DeTECHtives, we as facilitators would look through the worksheets and then hand them back. As we did, we often suggested the children show the worksheets to anyone they know who is an engineer by profession. When we gave the children the take-home worksheet during Think Like an Engineer, we explained that engineers draw objects from different points of view, and again we suggested that they show their drawing to any engineers they know. On several occasions, an adult in the group responded to these suggestions by identifying a specific family member, such as a parent or grandparent. While it is impossible to know whether children truly did show their worksheets to family members, the fact that adults suggested someone specific indicated an increased possibility for future conversations about what the children learned. Family conversation, as we discussed in section 2.3, is a strong indicator of lasting learning.
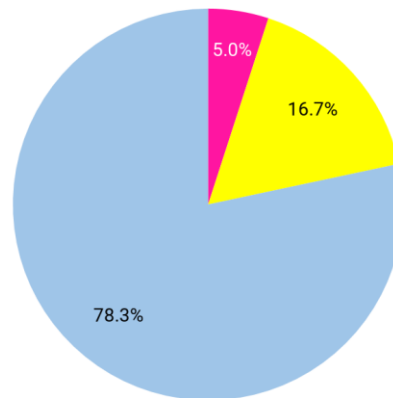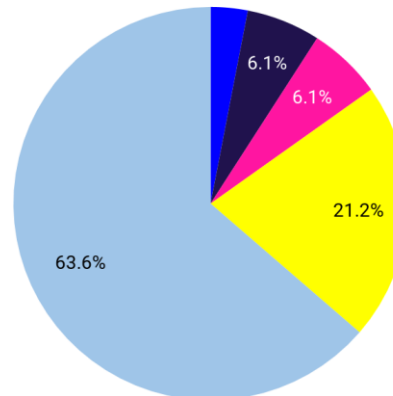

Figure 13: Action, Behavior, and Progression comment card data

On the comment cards, the statement that corresponded to Action, Behavior, and Progression was "I would like to come to the Museum of London again and do more activities." Figure 13 shows the distribution of the five levels of agreement to this statement for both activities. For DeTECHtives, 95% of participants expressed agreement with the statement, while none expressed disagreement. For Think Like an Engineer, about 85% of responders expressed agreement with this statement, while about 9% expressed disagreement. As previously discussed, agreement to this statement does not necessarily imply the respondent enjoyed our activity, as there are many other reasons one may want to return to the museum. However, the majority of respondents in both activities ranked this statement and "This activity was interesting and engaging" similarly; a response of 4 or 5 to one statement usually corresponded to a response of 4 or 5 to the other. This correlation suggests that most participants who enjoyed the museum as a whole enjoyed our activity as well.

4.4 Comparison Between Activities

The Think Like an Engineer and DeTECHtives activities are structured differently, so the information we gathered and the feedback we received varied largely. Several key factors set the activities apart, such as session dates, delivery locations, and the format of the activity.

Due to complications when printing the Think Like an Engineer map, we were unable to offer that activity until we received the map on Thursday the twelfth of April, late in the second week of activity delivery. As a result, we added an extra day of delivery that weekend in order to obtain as many observations and feedback forms as possible before the end of the Easter holiday. The data we gathered on Saturday the fourteenth of April suggested that comparatively few families visit the Museum of London on the last weekend of the half-term. The decreased number of activity participants may also be a result of the exceptionally warm and sunny weather that day, and a change in the location of the activity station.

We still conducted the Think Like an Engineer activity in the foyer that day, but museum staff asked us to set up our station on the opposite side of the room to stay out of the way of the security checking station. Our initial location was nearer to the entrance to the galleries, so visitors had to pass us on the way to everything but the gift shop. When we set up the station on the opposite side of the foyer, families could enter the museum and proceed to the galleries without noticing our sign or table. The amount of traffic past the station influenced the number of participants because a child pointing to the table often prompted families to approach the activity. The effect of such a slight change in location suggests the role that accessibility plays in activity participation.

Accessibility includes both physical and developmental considerations. We received several comment cards that expressed that younger children had difficulty doing the DeTECHtives scavenger hunt. In response to this feedback, we adopted the practice of asking how old the children were in order to advise parents that the activity may be too advanced, and for Think Like an Engineer, we added a suggested age range. Because we continued to receive children outside the age range during the DeTECHtives activity, we expected that younger participants would still want to try the Think Like an Engineer activity; in fact, we still facilitated

for children outside the "Best for 7+" age range, particularly in cases where they were in a group with older siblings.

The activities also differed in structure and duration. DeTECHtives was a scavenger hunt that consisted of a brief hands-on introduction and a worksheet that led participants around the galleries to find examples of simple machines. We did not ask participants for their feedback until after they had explored the museum with the worksheet, at which point several hours may have passed and family members may have become tired. This could have affected the feedback received when families returned to the activity station to get their reward stickers. The Think Like an Engineer activity, on the other hand, was a stationary activity that lasted approximately five minutes and only included elements at the station. We asked families to fill out comment cards immediately after the activity. For both activities, the brief amount of time each family spent at the station may have hindered the observation of the full extent of the GLOs that occured within the activity. This is also a concern for DeTECHtives, because most of the activity took place outside our scope of observation, so it is possible that additional GLOs took place beyond our observation.

5 Conclusions and Recommendations

With consideration of relevant literature and analysis of observations and comment cards obtained during our activities, we have reached our main conclusions about family activity design:

- A visually appealing and friendly environment draws and maintains visitor attention.
- Activities receive a more positive response than they would otherwise when they appeal to a wide range of ages.
- Facilitators have a limited amount of time to interact with participants and must use this time effectively.
- STEM activities in particular are effective when they relate concepts to aspects of children's lives.

For each of these conclusions, we have developed a corresponding recommendation for family activities, specifically STEM-focused family activities, for potential future use at the Museum of London.

5.1 Conclusions

Our first major takeaway from our findings was that a visually appealing activity draws visitor attention, while an amicable atmosphere maintains it. As the chalkboard sign we used for the DeTECHtives activity attracted visitors to our table, a similar visual element may serve the same purpose for a different activity. Not only would a sign add visual appeal, but it could serve as a simple explanation of what the activity is. As Sandra Hedblad mentioned in our interview, children are likely to become involved in an activity if they know their place immediately, without anyone having to explain it to them (2018). A display that identifies an activity as a scavenger hunt, for example, allows this immediate understanding.

The facilitator fosters an amicable atmosphere when they show enthusiasm in both speech and behavior, which is essential in maintaining visitor interest. Excitement and energy on the part of the facilitator were consistent factors in all the school group activities we observed, and we included them in our own activities accordingly. While a loud, energetic tone was effective in engaging outgoing children, we also found it beneficial to adjust to a softer, gentler tone of voice for shyer children. Talking in this manner allowed children to become more comfortable talking to us and engaging in the activities. Several comment cards included positive feedback about our attitudes, including "Great explanations at the beginning - lovely attitude with the children."

Another major takeaway is that activities receive a more positive response when they appeal to a wide range of ages. One of the most common responses we received from the comment cards for DeTECHtives was that the activity was too difficult for a younger child, for example "A little bit too complex for a 5-year-old but he did try." Typically the child was on the young side of the age range, around four or five years old, when the activity became too challenging. In contrast, aspects of our activity that did appeal to different age groups garnered

positive attention; younger children enjoyed playing with the simple machine toys on the table, while older children enjoyed the scavenger hunt aspect. Including aspects for both age groups attracted more attention and brought the whole family together for the same activity.

We found that an important aspect of activity design was making good use of given time; facilitators have a limited amount of time to interact with participants and must use this time effectively. While a school trip activity in a classroom like those we observed can examine material in more detail, for an activity like DeTECHtives, where facilitators only interact with a single family for around two minutes, it is essential to communicate the most important information as concisely as possible. We were able to maintain most children's attention during the entire DeTECHtives introduction.

One major takeaway specific to STEM-focused activities is that these activities are effective when they relate concepts to aspects of children's lives. One aspect of our DeTECHtives activity that consistently elicited a response was the comparison of the lever toy to a seesaw, a familiar object to most children who participated. By linking the new simple machine concepts with familiar concepts, the children more readily accepted the new ideas and learned something new. Additionally, participants often responded positively when we mentioned showing the worksheet to someone the children know who may be an engineer; at times, adults would mention a specific relative. The more direct connection to their engineering adult helped to bring the activity topic closer to their own experiences while also directing them to a source of further learning.

5.2 Recommendations

Based on our above conclusions we recommend that the Museum of London incorporate the following into any future STEM activities they develop.

Use bright colors and appealing signage. In order to attract children and families, use colorful items in the activity display (for example, sample items on the table) and on the signage. Bright colors catch attention and indicate that the activity is child-friendly. Place a sign near the activity station to tell visitors what the activity is, for example a scavenger hunt, without the visitors having to come over and ask. Include direct references to a STEM discipline, such as engineering or computer programming, on the sign. This will make potential participants more prepared for the activity's focus.

Adopt a charismatic attitude. Enthusiasm makes the activity inviting and exciting, so activity facilitators should strive to maintain a lively attitude. As section 2.6 describes, humor, praise, repetition, and the use of different vocal intonations for emphasis are important tools for activity facilitators. Repetition and emphasis are particularly effective when teaching children new vocabulary words that relate to STEM concepts.

Design activities to be flexible and variable for children of different ages. STEM topics are often difficult for young children to fully understand. To address this, family activities

should include elements for children of different ages so that all siblings can be involved. Make handout-based activities such as the DeTECHtives scavenger hunt with a few very simple tasks so that younger children can do some elements, and will not be discouraged if they need to skip the more difficult challenges. In a hands-on activity, leave some elements for younger audiences to explore while older children are participating in the demonstration or listening to the activity introduction. Use scaffolding questions to make topics understandable for any age; when designing an activity or writing a Volunteer Pack, draft several sets of scaffolded questions for participants at different levels.

Optimize the time each participant will spend at the activity station. Plan out your explanation before delivering it on the museum floor. Make detailed Volunteer Packs with activity descriptions, sample scaffolding questions, and intended learning outcomes. Identify the main concept that children should take away from the activity, and choose demonstrations, questions, and activities that repeat and emphasize that concept. The facilitator needs to be succinct and clear to convey different STEM topics. Clarity aids in the understanding of new or difficult material.

Make the topic relatable to children. This is particularly useful for a STEM-focused activity because it makes the topic more understandable. There are three main ways to connect concepts to children's lives:

- Connect elements of the activity to items that children see in their daily lives, for example comparing the lever model to a playground seesaw.
- Connect elements of the activity to people that the children know; in the case of an engineering-themed activity, encourage them to take home their activity sheet and show it to family members who work in the engineering industry.
- Connect the activity to the National Curriculum in England, as suggested by Sandra Hedblad. The National Curriculum has a designated section of Design and Technology programs, so when developing a STEM-based activity, select themes that correspond to topics that children may have already learned about in school. Using the National Curriculum ensures that the children have been or will be exposed to similar material and the activity builds upon structured material.

5.3 Discuss New Activities

Using the findings from the delivery of our own activities, we developed seven ideas for potential future STEM-based activities. These ideas all relate an aspect of STEM to either an existing exhibit at the museum or to London's history and culture. We describe these activities briefly below, and we show sample Volunteer Packs for them in Appendix H. We chose to produce additional activities beyond the ones we delivered in order to give the project a more lasting impact. We hope the Museum of London will be able to build on our ideas as they continue promoting STEM education.

We developed these potential activities to expand upon our work on Think Like an Engineer and DeTECHtives. They address areas that we felt had room for improvement or that we had not considered when developing our initial activities. For example, every activity description includes an age considerations section, which includes aspects of the activity that allow children aged five and under to participate. Additionally, when choosing ideas, we included a variety of types of activities in order to appeal to different learning styles.

The first activity, the Fire Pyramid Craft, connects the Great Fire of London to a scientific concept called the fire tetrahedron, or fire pyramid. The idea behind the fire pyramid is that four elements are necessary to make a fire: oxygen, heat, fuel, and a chain chemical reaction, because the energy from one combustion reaction is needed to spark another. Without any of these four elements, fire cannot exist. After an introduction about the Great Fire of London, the activity asks children to build and decorate their own paper pyramids but instead of fire the topic would be another aspect of their lives. An example is which four ingredients are needed to make their favorite food. The crafting aspect is helpful for visual and kinesthetic learners, as participants receive the opportunity to work with their hands and create a physical representation of the concept.

Here to There: Transportation through History is an activity trail for families that focuses on different methods of transportation displayed in the galleries and their power sources. Participants follow an activity trail card that guides them to examples of vehicles in the galleries, such as the model ships in Roman London and the taxi in Expanding City. The trail asks participants to identify the power sources of each vehicle, and to discuss why it replaced the power sources of the previous time period. The activity concludes by asking children to think of renewable energy sources that may be used to power vehicles in the future. The discussion element among children and their families encouraged by an activity trail benefits interpersonal learners because they communicate their ideas and thought processes.

Activity Trails with Augmented Reality is an expansion on the DeTECHtives scavenger hunt. Using a tablet or phone with the appropriate app, participants can scan special AR tags near the simple machines in the galleries and see a graphic on the screen that shows how the machine operates. A three-dimensional image of the simple machine will appear on the screen in a way that allows the user to view it from different angles by changing the position of the device. The ability to manipulate the machine in 3D space is a useful feature, particularly for visual learners.

The Real World Robots activity is based on tools in the World City gallery: cargo hooks from dockworkers, a baker's mixer, glassmakers' tools, and type letters from a printer. A worksheet asks participants to consider how these jobs used to be performed, as well as how they are done now; these jobs are primarily automated, or performed by machines. The goal is to understand that engineers design robots to do slow or dangerous jobs more quickly and safely. The worksheet asks participants to think about which jobs may be performed or aided by robots

in the future and draw their interpretations of robots. The independent worksheet structure of this activity can benefit intrapersonal learners.

The Ada Lovelace Performance teaches the basic thought process behind computer programming. It stars an actress playing Ada Lovelace, a Londoner considered to be one of the first computer programmers because of her work on Charles Babbage's Analytical Engine. In the performance, she follows audience directions to perform a simple task that has multiple steps, such as making a cup of tea. However, she interprets the instructions very literally; for example, if the audience tells her to put milk in the cup, she might pour out the entire carton. The goal of the activity is to help children understand that computers need precise, detailed instructions in order to function properly. The interactive and physical elements of this activity may appeal to kinesthetic learners, and the precise directions necessary may make sense to logical learners. The sequential explanations help logical learners understand the patterns and parameters involved in computer programming and how to create their logical commands.

Shop Like a Roman is another worksheet activity. The worksheet has illustrations of different Roman coins and items in the Roman London gallery that a Roman person may have bought at a market, and specifies a value for each. The participant must determine which combination of coins they would use to make each purchase. As with the Real World Robots activity, the worksheet approach is good for intrapersonal learners as well as visual learners because of the included images of the coins on the worksheet.

The final proposed activity is Automation for Safety, which takes the form of either a classroom session with videos, or QR codes in the galleries that link to the videos. This activity centers around the lathe in the Expanding City Gallery. It shows participants video examples of an old-fashioned, foot-powered lathe, an electric lathe that is still operated by hand, and a a fully automated modern lathe. At each stage, the activity facilitator or worksheet asks participants to think about how the machine might be dangerous for the operator. The goal is to understand that because there is almost no human intervention needed to use the automated lathe, it is much safer than the older examples. The videos involved may appeal to visual learners and the search for the QR codes within the gallery may appeal to kinesthetic learners.

5.4 Final Thoughts

The Museum of London hosts hundreds of family activities each year, but there are always new techniques to try and new topics to explore. While developing our STEM-based activities, we were amazed at the depth of STEM throughout history, and excited by how many children were eager to learn about science and engineering. It was inspiring to see how many children are growing up with the goal of becoming engineers. We hope that our activities and recommendations will help the museum attain its goal of inspiring every citizen and visitor of London.

Acknowledgements

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Appendices

Appendix A: Museum of London Information

The Museum of London began as two separate museums: the Guildhall Museum, opened in 1826 with a focus on archaeology, and the London Museum, opened in 1912 with a broader range of interests. In 1965, the two were combined to form the Museum of London. Its current location at the London Wall opened in 1976, and a second location, the Museum of London Docklands, opened in 2003 ("Our organisation," n.d.). Today, the two locations combined receive over one million visitors, with 1,085,038 visits to the museums in 2016/17 (Bannister, Ament, Gowman, & Thornton, 2017). In addition to its two main locations, the museum runs the Museum of London Archaeological Archive, which includes the Centre for Human Bioarchaeology, in Hackney ("Our organisation," n.d).

Figure 14: Museum of London, London Wall Exterior

Figure 15: Museum of London Docklands

Like all museums, the Museum of London's three main roles are education, maintaining historical collections, and research. The objective of the Museum of London is to educate and inspire every citizen and visitor of London from an early age and become a part of London's "international, educational, cultural and economic" impact ("Our strategy," n.d.). Museum education spans from exhibits and on- and off-site programs to web-based resources. There are over one million objects in the museum's internationally renowned collections, and over 66,000 objects are accessible via Collections Online (Museum of London, Inspiring 2012). Within its facilities, the museum hosts exhibits and research opportunities spanning all of the city's history including the Roman era, the Medieval era, the Great Fire of London, the Modern era, and British seafaring history. There are also rotating temporary exhibits on a variety of topics such as Un(Common) Currency: Currency from 18th century to present, Keeping Warm: 19th & 20th century ways to beat the cold, and Imagined Futures: Visions of the future of London.

Figure 16: (Un)Common Currency

In addition to permanent displays and special exhibitions, the Museum of London offers a variety of programs for families and schools. Teachers can book self-guided or facilitated group tours, and sign up for interactive activities such as the *Victorian London* session, in which students develop a Victorian character profile and try on replica costumes. There are also off-campus programs, such as the *London Mithraeum Field Trip*; students spend 90 minutes at a reconstructed Temple of Mithras, then walk back to the London Wall for a guided tour of the Museum of London's Roman London gallery. Throughout the year, the Museum of London also hosts "family festivals" and programs designed for young children and their families. These programs generally include a combination of museum group tours and hands-on activities. A common program format is a family walk, during which families are guided through galleries and even nearby locations to learn about a major event or era in London's history. A recent example is the *Great Fire of London Walk*, which visits galleries and locales relevant to the Great Fire of 1666 and helps children learn about its possible causes using interactive "mini challenges" (Museum of London, n.d.).

Some programs allow children to interact directly with museum artifacts and materials. Currently, the museum is running *Archeology Detectives*, a program during which children are given real historical artifacts such as medieval shoes, which they can examine and hold in their hands. According to the program page, the children are encouraged to use the artifacts to "uncover London's past" and learn about the daily lives of Londoners throughout history. This program teaches schoolchildren about London's cultural history, and demonstrates how archeologists uncover and analyze evidence ("Archaeology detectives," n.d.).

The Museum of London is currently nearing the end of a five year Strategic Plan developed to guide the museum's activities from 2013 to 2018. The Strategic Plan is designed to be a "road map" that contains "five strategic objectives [that] will ensure that the Museum of London delivers the very best for [its] audiences" (Inspiring a Passion for London: Strategic Plan 2013 - 2018). The strategic objectives are as follows: to reach more people, to become better known, to stretch thinking, to engage every schoolchild, and to stand on their own two feet financially. These are broken down into clear measurable goals, such as attracting 1.5 million visitors each year by 2018, getting involved in ten big London issues, engaging over 850,000 schoolchildren, and generating £100 million total income ("Inspiring a Passion for London: Strategic Plan 2013 - 2018," 2012). To reach those goals, there are eighteen governors who oversee museum management. Each one has their own respective background such as politics, art, and history. Together they govern the different branches of the Museum of London including The London Wall, the Archaeological Archive, the Centre for Human Bioarchaeology, and the Docklands Museum. The Museum of London's London Wall and Docklands locations are shown in Figure 17.

Figure 17: Museum of London Campus Locations

City Now, City Future is a year-long series of events and exhibits that explores varying facets of urban life. There are over 100 programs in the series, with each exploring a different element of urban life from air pollution and low emission neighborhood gardens to women in video games and LGBTQ night life spaces. ("City Now, City Future" n.d.). Programs like City Now, City Future are a crucial part of the Museum's Strategic Plan. They "stretch thinking" by tackling modern issues and generating new exhibits, rather than just utilizing the existing collections. The City Now, City Future season is able to reach more people and help the museum become better known because it lasts for twelve months, rather than a single short exhibit or event that lasts only a few days or weeks. The IQP, to develop and deliver a set of family activities for the Easter holiday program, is intended to help reach the goal of engaging schoolchildren.

The Museum of London has much to offer to the visitors and citizens of London. Their five year Strategic Plan and upcoming relocation to West Smithfield will aid in their missions for outreach and education. We are excited to be involved as the museum evolves and grows alongside the city.

Appendix B: Activity Ideas
Lego Mindstorms Robot:

Background/Basic concept: Robots and automation are becoming increasingly prominent in many aspects of life. Programming is required for automation to work.

Activity: Provided with a basic Lego Mindstorms robot, children would be shown how to use the drag-and-drop programming to make the robot complete a simple challenge (for example, drive forward, turn left, drive backward, turn right, and drive forward)

Materials: Lego Mindstorms kit

Advantages to this idea: The robot kits can be bought with all necessary pieces included. The "code" is drag and drop blocks, which are easy to understand.

Concerns about this idea: The robot kits are expensive (not less than $150 USD) and only the basic parts would be used. Even if buying one, it would limit the number of people able to do the activity at once. Time would be lost to charging it and the accompanying computer between uses. The specifics of the programming may be too advanced for five- to eight-year old children.
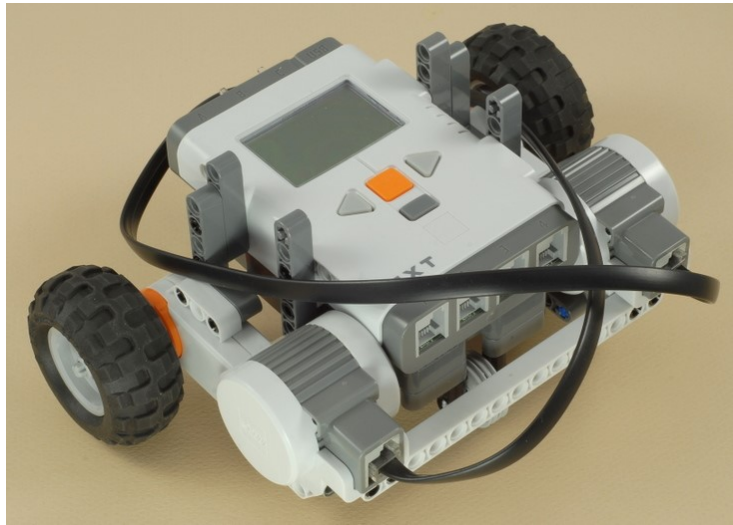

Figure 18: Basic Robot

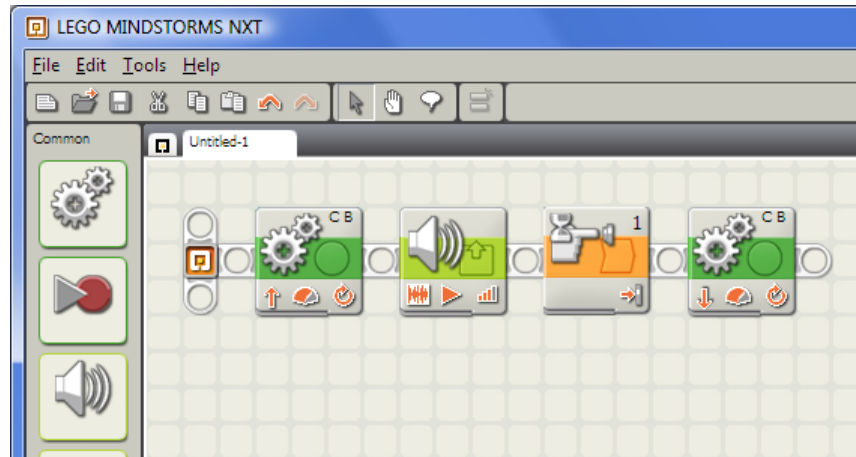http://www.nxtprograms.com/five_minute_bot/index.html

Figure 19: Lego Programming Interface

Programs for Lego robots are created by linking blocks for different functions - driving motors, triggering sensors, etc.

Think like a Future Archaeologist:

Background/Basic concept: Archaeologists draw conclusions based on their findings. However, it is important to note that often only a few artifacts are found, only an incomplete image of the past is shown.

Activity: Several items would serve as props from the past. Based on the item itself and the context the item was found in, participants would be asked to deduce what the item is and how it may have been used in the past. The true answer could be revealed later on. After this revelation, participants would be asked about artifacts from today, and how they may be interpreted thousands of years in the future. An example could be why Fatberg occurred and why it is displayed. The activity would teach children to make logical conclusions based on limited information and how to re-evaluate them with more information. Participants should recognize the gaps in their deductions and understand the implications in our current understanding of history.

Materials: Sample artifacts from past and present (children wouldn't be touching actual collection materials; ideally use recreations and things used for other hands-on activities)
Advantages to this idea: It really encourages thinking outside the box.

Concerns about this idea: It may not fit with the futuristic theme of this portion of City Now, City Future.

Playground Planning/Urban Planning: (This activity could be implemented in several different ways: on a larger scale, planning elements of a whole city, or on a smaller scale, planning a playground.)

Background/Basic concept: As the world's population grows, it is becoming increasingly important to optimize the layout of urban areas.

Activity: Children can design their own city (or playground). They are encouraged to plan what they will need to include (cities may need a school and a library, a playground may need a slide or swings) and how those elements may interact (if a city has two libraries, they shouldn't be side by side; on a playground, a swing set should not be placed right in front of the exit of a slide). Children can then "create" their city or playground by drawing it, building it with blocks and figurines, or using a program on a tablet or computer.

Materials: Depending on which approach: paper and drawing materials, blocks and figurines, or tablets.

Advantages to this idea: Asking questions about what cities need to have can encourage children to think outside the box and may encourage dialogues about places children go and things they need in their everyday lives.

Concerns about this idea: It may be too open-ended. The breadth of things to consider may be overwhelming for young children. Access to tablets is not guaranteed.

Think Like a Computer:

Background/Basic concept: Computers can be programmed to determine optimal results. Future cities may be populated by self-driven cars, which may have the ability to locate nearby available parking spots.

Activity: Children can choose a figurine vehicle, and place it somewhere on a basic map that has a grid printed over it, as seen in Figure 11. There are marked places on the map with available parking spots. Children can count grid squares from their position to determine which parking spot is closest. The goal is to help children understand that because computers can't "see" like humans can, they have to use math instead; a human may be able to see that a particular parking spot looks closer than another, but a GPS system has to calculate the distance from current position down drivable roads to each spot to determine which is closest. Complexity can be added by making some roads One Way only, or by asking children to choose parking spots with "destinations" on the map in mind (for example, if going to a pet store, the ideal parking spot may not be one closest to the car's current position, it may be a spot at the end of the route to the store).

Materials: Printed custom "map" with grid overlay; toy vehicles; dry erase boards or paper for basic math.

Advantages to this idea: The math is very simple (for example, counting eight grid squares forward, then turn and count three to the right) but it makes an important point about computer logic.

Concerns about this idea: It may be considered "boring."

Figure 20: Think Like a Computer Map Example

Design a Green Roof:

Background/Basic concept: There is a growing movement to implement "green roofs" on top of buildings in both cities and suburban areas. Planting vegetation on top of buildings has many benefits, including air purification, temperature reduction, and reduction of stormwater runoff.

Activity: Children will be invited to "build" their own green roof out of model pieces. Within a designated "roof" area, they can lay out differently shaped wooden or plastic pieces representing

different types of plants (vegetables, flowers, moss) and pipes or barrels for rainwater management systems.

Materials: Table or other workspace; wooden or plastic figurines that can be made to look like garden beds and labeled with types of plants they represent; tubes and barrels for runoff

Advantages to this idea: There are many ways to modify complexity levels for different audiences. A basic activity may pose simple restraints (for example, your garden must have at least two rain barrels and three areas with moss). Additional elements can be added to increase math or critical thinking (for example, there are only 20 units of plant food, and if each flower bed needs 3, each vegetable patch needs 5, etc. Maximize the number of plants that can be fit on the roof with the given resources).

Concerns about this idea: If each flower bed is its own piece, and if there are differently shaped tubes (straight pieces, corners, etc.) there may be too many pieces on the table to manage effectively.
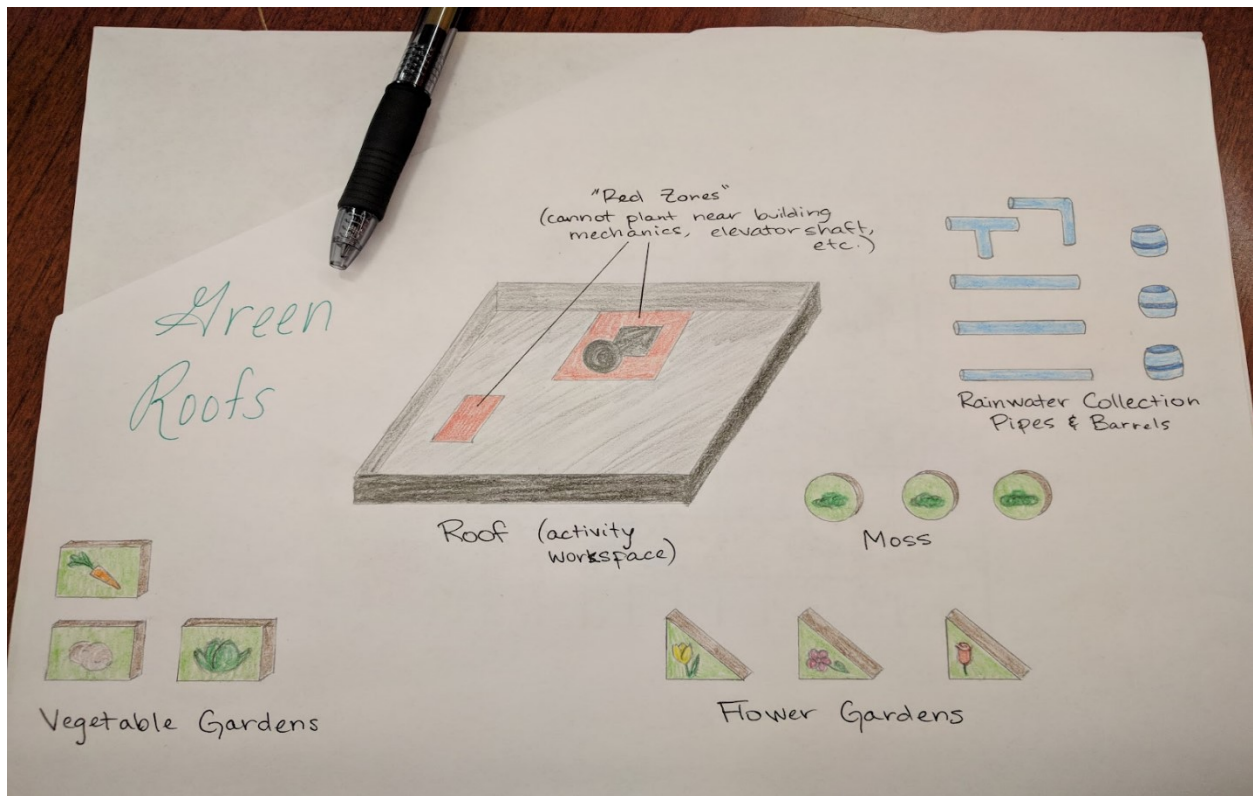

Figure 21: Green Roof Preliminary Sketches

Appendix C: Preamble for Activities

We are a research team from Worcester Polytechnic Institute, a university in the United States. We are working with the Museum of London to develop hands-on Science and Technology themed activities for families. We are here to observe people's interactions with these activities, which will help us develop better activities. Participation is voluntary. Please let us know if you have any questions or concerns.

Appendix D: Interview with Sandra Hedblad
15 March 2018, 1pm
Interviewers: Sean Fraser, Tessa Garbely

Preamble: We are students from Worcester Polytechnic Institute, a university in the United States. We are conducting research with the Museum of London to design STEM-based activities to promote family learning. We will be delivering two London Visions activities during the Easter holiday program, and we are conducting this interview to better understand what makes activities engaging for families. Would you be willing to answer a few questions about your experiences and knowledge of family programs at the Museum of London? Would you mind if we quote you by name in our final report? We will give you an opportunity to review any quotations before publication. Alternatively, if you prefer, we can anonymize your responses.

- Your position title is Senior Family Learning Manager. What are your responsibilities at the Museum of London?
    - I manage the family team, I manage Cass and Cass manages Anna, they did a big open day with families. I also manage Victoria, our early years (under five years old) manager. I also manage the equivalent of Olivia at Docklands (Claudia).
    - I oversee all the family work that learning is involved in. Family festivals, school groups, exhibitions, etc. I am also involved with activity development.
    - For 9 years I had a more direct role in designing activities for families.
    - I often sit down and plan the programs together, but then they carry it out.
- We have noticed a variety of tables and stations with activities throughout the galleries. What elements do you focus on including to make activity stations appealing?
    - First thing is the topic. Are you just thinking what it looks like or the overall concept? ("Overall concept") Pick a topic from the National Curriculum, or something children are enthusiastic about. The topic is important. In terms of look, I find it's easier to not just have a big table. You need a reason to go over there, a draw of some kind.
    - It tends to attract people if there are other people there.
    - Things we know really work include open play. If children see an activity and know they can get involved with it, it helps if they know their place immediately, rather than having it be explained to them.
- Olivia mentioned that for some events, activities are set up at tables in the foyer. Are there specific locations within or outside the galleries that attract more participants than other areas?
    - Sometimes we've done things outside the main entrance. We did a lot on the back wall of the foyer too. It works because it is a central location, with the shops and the entrance to the galleries.
    - The location you choose depends on the activity. The foyer is good for people who just arrived, but if you put it further in you can refer to anything they've

already learned. They have events scattered across different galleries, so families go to different stations. Then things are book-ended by the foyer.

- If it's messy, it can't be in the galleries.
- It's a big draw if it's something they can't do at home or anywhere else.
- Instead of worrying about the location, it's better to decide on a suitable activity and then people will come. ("Where should we go so people are interested?")
- Things to take into consideration - the aside activities rooms (learning center) remember that people will have to go off the standard path. As for the messes, there are restrictions in the galleries (for example, need to use glue sticks instead of liquid glue.)

- What are some examples of activities that were designed with specific museum exhibits (either permanent or temporary) in mind?
  - We try to have all our activities connect in some way to museum content. But they sometimes have activities in particular spaces that add atmosphere (like the event held in the Saxon house). They have done things on the Victorian Walk, and in the Pleasure Gardens. That's just one way to connect with topics and get submerged in the environment.
  - Another way to do it is to pick an object in the collection and build an activity around it. We do that with all of our events. For example, make a Roman mosaic (ties to the mosaic floors in the museum) or have a flint knapping (the shaping of flint through the process of chipping away) demonstration in the London Before London exhibit.
  - Sometimes there are activities about what is done in the museum, like archaeology. How they find objects, how they find out about objects, etc. How does the museum function? How do we make choices about which items to put in the museum?
  - Activities telling a story. In addition, sometimes they bring in people from outside (freelancers - an example, illustrating how x-ray works).
  - Some people come in to learn about Romans, so they design activities to help with that.
  - I developed an archaeology trolley. One activity is about animal bones. They could have evidence on the bone of human intervention, such as marks from knives. Other activities to do with archaeology include making a replica of something. If you think about a round house with a thatched roof of straw, a lot of the homes have a hole on top. A lot of archeologists interpreted that as a chimney, but through testing they found out it couldn't be a chimney, it didn't work at all. In fact, if you close the hole up, smoke disperses and you don't even need a chimney. (The point - in archaeology you can't always tell by looking at something, sometimes you need to test it.)
  - There's no reason families can't learn through discovery like museums do.

- ("So archaeology related activities are some of your favorite?") Yes. And it also helps people learn when they can do things themselves. But it doesn't have to be that way, even just watching a show can be successful.
- How do you determine if an activity station is successful? What indicators do you look for while observing participants?
  - We would do some evaluations of events, ask if families enjoyed it.
  - Reporting structure
  - 90% of visitors should say they enjoyed the activity.
  - Another thing to ask is "Was it well organized?" As an organizer you want people to say yes.
  - For me, it would be a success if people learned something. We evaluate learning against GLOs. For us, learning is a lot broader than skills or knowledge ("or getting a good grade on a test"). It is a success if any of the GLOs are fulfilled. It could even be a success if they learned that they like museums/ even if they didn't learn anything about the subject matter or topic.
- What is your favorite activity that you have been involved in? What made it stand out to you?
  - I've been here for 14 years, we probably do about 500 events per year. A whole festival I did on cycling. A small display of cycles through the ages. We introduced the rentable cycles in London. We had mainly focused on school and holiday activities but they had extra money so they shoved the extra budget into one big weekend celebration of cycling. That was the first festival the museum ever did. The reason it was successful was that it covered something people could identify with. It was also a challenge to see how many things you could do with one single object. As an example, a cycler came in and did a bunch of cycling tricks and showed little kids how to do them. They also did something about the cycling police (police on bicycles). In London it is congested (hence the significance of bicycles). I challenge people to understand one object in many iterations.
- {Describe idea for Archeology Detectives activity}
  - You'll probably need to choose those objects and what they are to make those links. You might not get much evidence out of a wrench. Certain objects, regardless of if they have been used or not, look the same. (Teeth - wear and tear, used to sharpen things) Think about the modern thing (modern version of the item) - needs to be easy enough for people to come up with answers. It's a nice idea to link it back to the past. Use these as our clues. (Use past objects as clues?)
  - It's interesting how people can distance themselves from the present.
  - As an activity, it can work. You just need to choose the right objects. iPad could be a modern item. A ball - are they going to be the same in the future. ("Different balls from different sports? Do you know where we can find objects?") Handling
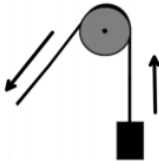
collections. (We've seen a session that used some of these objects.) There are more archaeological things in the archives, but you can also find things in the handling collection. Maybe we could go to Docklands (to see what they have and possibly get stuff.)

- Is there anyone else you suggest we speak to about these topics?
    - If you decide to go down an archeology route, it might be good to speak to one of the conservators. Learn how they handle objects. Attend some of the sessions that look at objects (we've done that).
    - Katherine (Kath) Davis is the Archaeology Learning Manager. **She will be leaving in March, so speak to her sooner rather than later.**
    - Speak to hosts in the museum, and go on tours of the museum.
    - It will be hard to choose from collections, since we're not familiar with them. Talk to hosts about what families are interested in.
    - Flint was the one and only sharp material of its time. Eventually, you'd have 100 items that are sharp. How will this change in the future? How many items will do the same thing?
- Comments on Think like a Computer: "I like the simplicity of that one." (The activity was still called Think Like a Computer at the time of the interview.)

Appendix E: Activity Worksheets

Pulley (Roman London)

A **pulley** is a wheel that a rope, cord, or belt moves around.

Find the pulley on the ship model.

What do you think the Romans lifted with the pulley?

Challenge:
Can you find the hidden pulley in the grain mill?

Pulleys have been in use since Roman times. There is an old-fashioned lift in the People's City gallery. A complex set of pulleys called a bolt and tackle system is used to raise and lower the lift.
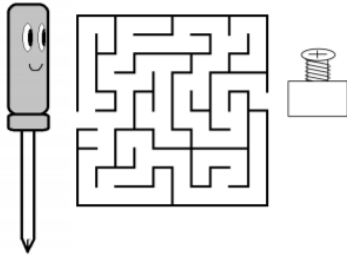
Screw (World City)

A **screw** is a ramp wrapped or twisted around a **cylinder**.

The Museum of London

Screws are used everywhere today.

How many screws can you count on the digital switching card in the World City gallery? (Hint: It's in the same display case as the old telephones.)

_____

Help Phillip the Screwdriver find the loose screw!

Congratulations! Come back to the table to get your sticker!

Engineer Word Bank

Simple machines   Wedge   Pulley

Ramp   Inclined plane   Lever

Fulcrum   Axle   Wheel   Screw   Cylinder

DeTECHtives

Simple machines are tools with few moving parts that make work easier. People have been using these machines for thousands of years.

Can you find these 6 simple machines hidden throughout the museum?

You will be hunting for:

| Lever | Wheel & Axle | Screw |
| Ramp | Pulley | Wedge |

Challenge: There are a lot of wheels and axles in the galleries. See how many you can find!

Wedge (London Before London)

A **wedge** is used to separate, lift, or tighten an object.

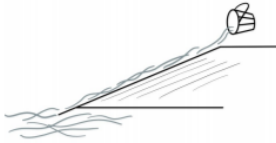Can you find an object prehistoric people might have used to split wood?

Circle examples of wedges at home:

| Knife | Toothbrush | Soap |
| Nail | Doorstop | Chair |

Figure 22: DeTECHtives Worksheet (side 1)

Ramp (Roman London)

A **ramp** is a surface that is angled or sloped, which connects a lower level to an upper level. Another name for a ramp is an **inclined plane**!

Find the drainage ramps leading out of the Roman bath house.

Do you see any modern examples of ramps around?
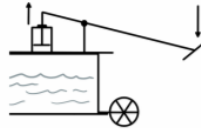
Yes ☐   No ☐

What would have happened if the Romans tried to get rid of unwanted water on flat ground? Discuss with your grown up.

Circle the examples of ramps below:

Inclined Plane	Slide	Axe
Pencil	Stairs	Computer

Lever (Great Fire of London)

A **lever** is a board or pole that rests on a central stand called a **fulcrum**.

Can you think of any examples of levers at home or at the playground? Draw them below.
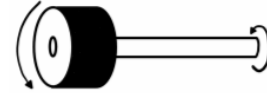
Find the fire engine.

How many people did it take to use the fire engine? (Circle one.)

12   4   5   1

Why do you think they used this fire engine? Why not just use buckets? Discuss with your grown up.

Wheel & Axle (Victorian Walk)

An **axle** is a rod that goes in or through the **wheel** to move it, and keeps the wheel in place as it turns.

Find one of the food carts in the Victorian Walk and draw it below.

Who used this cart?
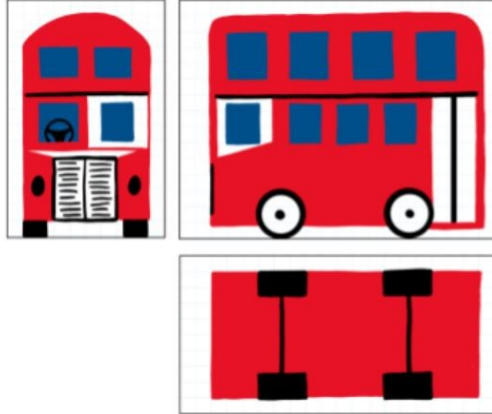
What would it be like pulling or pushing the cart without any wheels? Discuss with your grown up.

If you did the challenge at the beginning of the scavenger hunt, how many wheels did you see today?

Figure 23: DeTECHtives Worksheet (side 2)

Design a Car from the Future

When engineers design cars, they first draw it out from several different points of view: from the front, the bottom, and the side. To the left is an example of how they might draw a bus. In the boxes below create your own car from the future. What do you think cars will look like in the future? Will they drive themselves? Will they look like they do today?

Front

Side

Bottom

Figure 24: Think Like an Engineer Worksheet

Appendix F: Volunteer Packs

These volunteer packs are for museum staff or volunteers delivering these activities in the future.

DeTECHtives

Activity name	DeTECHtives
Equipment checklist	- Sample simple machines and accessories - Screw - Pulley - Wheel and axle - Lever (includes wedge/ramp as fulcrum) - Weights - Scavenger hunt worksheets - Pencils "Trainee Engineer" stickers
Overview	Participants receive a brief introduction to simple machines: there are six types, and they make work easier. Afterward, the activity challenges them to search for examples of simple machines throughout the galleries. The worksheet guides them toward one specific example of each type, but for an additional challenge, they may also search for further examples.
What to do/instructions	Because the activity takes place throughout the galleries, the role of the facilitator is to provide the introduction and conclusion. For the introduction, you may choose to begin with an overview of the activity or of simple machines.

Invite children to play with the examples of simple machines on the table. As they do, point out each simple machine and ask questions about it, such as physical properties like shape, how it moves, and what happens when someone uses them in a certain way. You do not have to identify the machines in any particular order, nor do you need to explain all of them.

After you have introduced the simple machines, make the transition to the scavenger hunt. Say that there are examples of all six simple machines throughout the galleries, and if the children can find them, they will receive a sticker. Distribute the worksheets and offer a pencil; in order to earn stickers, the family must present an at least partially completed worksheet upon returning.

For the conclusion of the activity, ask for the completed worksheet and ensure that there has at least been an attempt to complete the challenges. |

	The worksheet does not necessarily need to be marked; the family may share their findings verbally. Once the family has completed the activity, present the children with their stickers. You may choose to offer concluding questions about simple machines and their use throughout history. Encourage children to take their worksheet home and share it with their families, particularly any family members in an engineering profession.

Sample questions	Introduction:
	• How old are you? [Depending on age] You may have learned about them in school already, but there are things called **simple machines**. There are six of them, and they are designed to make work easier.
	• For example, what happens if you pull the [pulley] string?
	• If you had to lift something heavy, would you rather use the pulley or lift it up with your hands?
	• [About the lever] How about this, does this remind you of anything you've seen before?
	    o The answer should be "seesaw" to lead into the next question.
	• Have you ever been on a seesaw with someone a lot bigger than you - maybe a grownup? What happens?
	    o Accompany this question with a demonstration; a yellow weight on one side of the lever represents the lighter person, and a purple weight on the other side represents the heavier person.
	Concluding:
	• Where in the museum did you find these machines?
	• Where do we use these machines today?
	• What is something you or your family does every day that would be easier with any of the simple machines?

Learning outcomes	• Types of simple machines and their applications • Use of simple machines throughout history

Think Like an Engineer

Activity name	Think Like an Engineer
Equipment checklist	- City map 4 toy cars - Take home worksheets "Trainee Engineer" stickers
Overview	Participants think of what engineers must consider when developing a piece of technology, for example a self-driving car. They place a toy car on a map, and must decide which parking space is closest to their current location. Since computers cannot "see" like humans can, they must use maths-based logic, so participants must count the number of grid squares from their current location to each nearby parking space.
What to do/instructions	As children approach, introduce them to the concept of self-driving (or **automated**) cars and discuss what engineers must consider when designing them. Ask questions such as the first three in the sample questions section below. Afterward, invite them to select a car and a location, such as the pet store or cinema, where they would like to go. Instruct them to place their car in a square near their chosen location. The square must be on the road (not on a building or in greenery), and it cannot be on any space marked with a P. Pose the situation that this is the future, and their self-driving car has just dropped them off at the chosen location and must find a place to park, a square marked with a P. Ask questions such as those posed in bullets four through eight. When participants understand that computers must use maths, invite them to count the number of grid squares from their current location to each nearby parking space. The squares must be in straight lines along the road. For an optional extension of the activity, you may indicate the yellow and black barriers on two-way roads. Since a car cannot drive through this barrier, it must instead drive around it, which means that what appears to be the closest parking space may not require the least amount of driving. Ask children which space is now the closest, taking into account the barriers.

	At the end of the activity, show participants the take home worksheet, which allows children to design their own futuristic, self-driving car. Explain the concept of perspective drawing; engineers draw cars from several different points of view in order to visualize it. You may use one of the toy cars in order to illustrate this concept; by flipping it so that the front, side, and bottom are facing the participants, you can communicate the meaning of different points of view. It is not necessary that participants take the worksheet; they can also print off the worksheet from the Museum of London's website at home. At the end, award each child a "Trainee Engineer" sticker and compliment their hard work thinking like engineers.
Sample sequence of questions	- Do you think cars can drive themselves? - How long do you think it will be before you look out the window, and most of the cars you see aren't driven by a person? - When engineers are designing something, they need to consider what the product will have to do. What kinds of things do cars need to do? Drive, steer, park, etc. [Invite children to pick a location they want to go to and place a car on the road near the location.] - Pretend this is the future and the car has just dropped you off at the location. It needs to find a place to park to look for you. Can you show me which parking space is close to your car? Quick, point to it. - How do you know this is the closest? You saw it with your eyes. - But computers don't have eyes, so engineers need to program the computer in the car to be able to make decisions. - Have you ever been in a car with Sat Nav or used Google Maps? - Those both work using something called **coordinates**, which are numbers that a computer uses to tell where things are on Earth. - The computer in the car knows the coordinates of where it is, and where the parking spots are, and it has to use maths to determine which spot is closest. - How many squares is it from your car to the nearest parking spot? [For younger children, point and count with them] [For younger children, count to another square as well, compare the number, and ask them which distance is least.] [For older children, point out things like road barriers that may change their answer.]

	• These are all things that engineers have to consider so they can program the computer to make these decisions. • [Bring out worksheet] Another thing engineers have to consider when they design something is what it will look like. This is an example of a **perspective drawing**, or a drawing that shows different points of view, that an engineer might use to plan. • We challenge you to draw what you think a car from the future will look like, but you've got to do it like an engineer would. How will the car move? If it has wheels, or a hover machine, you could draw those on the bottom view. If it has headlights, draw those on the front, etc.

Learning outcomes	• Computer science principles
	    o Introduce the idea that computers use maths to solve problems
	• Collaborative problem solving
	    o Invite adults to help children decide which parking space is closest

Appendix G: Comment Cards for Activity Participants

Comments

We are a research team from a university in the United States, and we are working with the Museum of London to develop engaging Science and Technology-based activities for museum visitors. Your responses are completely anonymous and voluntary.

In which activity did you and your child participate?
[ ] Think Like a Computer
[ ] DeTECHtives

For either you or your child, please rate the following (1 = strongly disagree; 5 = strongly agree):

This activity was interesting and engaging.
1 2 3 4 5

I discovered some new information.
1 2 3 4 5

I learned how to do some new things.
1 2 3 4 5

This activity helped me see that museums can be fun.
1 2 3 4 5

I would like to come to the Museum of London again and do more activities.
1 2 3 4 5

Thank you for your feedback. Do you have any other comments for us?

_____

_____

Figure 25: Comment Card

Appendix H: Potential Future Activities

Title/Theme	Here to There: Transportation through History
Background	The Museum of London's galleries include different historical modes of transportation. For example, the Roman Gallery includes ships in a diorama of the Thames, the People's City gallery includes a model of a London taxi from the early 20th century, and the World City gallery includes a Vespa motorcycle. Engineers refine technology to improve how people get around. One important aspect of these modes of transport that changes is the power source. This ranges from wind and tides powering ships to petrol powering most modern day cars. These changes are a result of new scientific discoveries and how engineers apply them.
Activity description	This activity would take the form of an activity trail. Participants would be family groups, with children aged seven and older. Families have an activity trail card that shows them where to find methods of transportation in the different galleries, such as ships in Roman London and the taxi in People's City. The trail asks participants to identify the way each mode of transportation is powered. For example, water and wind move ships, horses pull carts, and finally petrol powers most cars today. At each step, they discuss with their adults why the power source changed. As an example: "Why did they start using petrol to power cars instead of horses?" At the end, children can think of possible ways we can power vehicles in the future, like solar power and wind power.
Age considerations	Younger children, especially those 5 and under, may have difficulty with comparing power sources. Instead, the activity can just ask them to find the vehicles in the galleries (the activity trail card would give the location) and possibly point out how they worked. For example, they know that a ship moves because of water and sails, and that carriages are pulled by horses. They can also point out details such as the number of wheels on the vehicle or its shape. Only older children who are familiar with solar and wind power would be able to complete the future power part of the activity on their own. Younger children could discuss it with adults and older siblings. They may come up with creative, if perhaps not feasible, ideas for power sources.

Learning outcomes	• Different types of vehicles, particularly their power sources, used throughout history • Effectiveness and environmental impact of different energy sources

Title/Theme	Automation for Safety
Background	Advancing technology in machining has increased safety in the manufacturing industry by reducing the role of humans in production. Before electricity became commonplace, foot pedals powered inventions such as sewing machines and the lathe on display in the Expanding City gallery at the Museum of London, and users moved the material through the machines by hand. As electricity became readily available, the foot pedals were no longer necessary, but the workpiece was still controlled by hand. Now, computers allow for complete automation; a human programs the shape into a computer and tells the machine which tool to use. A human loads in the material and the system processes it without further input. Afterward, it is removed, and a new piece is started, all without human intervention.
Activity description	This activity could take the form of a classroom session with a video, or within the galleries with QR codes linking visitors to the different videos. Participants visit the lathe in the Expanding City gallery. The facilitator explains what a lathe is (a machine that turns the workpiece to do things like cut, sand, and drill) and what it can be used to make (anything round out of metal, wood, or plastic: bowls, handles, pieces for furniture, etc.). The facilitator then challenges participants to think about how the lathe may have worked: the foot pedal turns the gears and belts, which turn the workpiece, and then the tool is slid over, and as the tool contacts the piece, it cuts away material. QR codes provide links to videos of three different types of lathes (or other machines, like sewing machines): the foot-powered one, an electric one, and a modern automated one. At each stage, the facilitator asks participants to think about how it might be dangerous for the person operating the machine (pinched fingers, spinning metal, shavings flying off, etc.) The goal is to understand that because there is almost no human effort needed for the automated lathe, it is much safer. The activity concludes with a worksheet/activity that asks children to think of a job that they think is dangerous or unpleasant (scary, smelly, etc.) and how they might design a robot to do that job so people do not have to. The goal is not to draw a stereotypical humanoid cartoon robot, but to actually consider how the machine might work. For example, a garbage collecting machine would need wheels to drive along the side of a street, an arm to

	reach out to pick up the correct colored bags, and a joint to lift the bags into the truck.
Age considerations	Using a sewing machine example may be more useful for younger children who may not understand machining and manufacturing. If they have seen a parent or relative use a sewing machine, it will be much easier for them to connect with the idea.
Learning outcomes	• Advancing technology has changed manufacturing • Automating dangerous jobs increases safety

Title/Theme	Real World Robots
Background	There are many misconceptions about robots that are fuelled by the media: what they look like, what they do, and how they work. The goal of this activity is to show that many real robots are used to do jobs more efficiently, and they don't always look the way they do in movies.
Activity description	Participants visit the World City gallery and look at the displays of tools. There are cargo hooks from dockworkers, a baker's mixer, glassmakers' tools, and type letters from a printer. The activity asks participants to discuss how these jobs are done now. It may be useful to have QR codes linking to videos of automated food production, molding glass, printing newspapers, etc. There are still bakeries, but most of the food in stores comes from factories where they can make many at a time. Glassmakers still exist as artists, but many of the cups used everyday came from a factory (they can be made quickly and more safely than having workers by a hot kiln all day). Typesetting and printing used to take a very long time, but now computers make typing and printing easier and faster. Many docks and warehouses now have machines to lift heavy cargo; machines can lift much heavier loads, and there is less risk of a worker getting hurt. The activity explains that robots are not necessarily the humanoid metal beings seen on television; they are just computer-controlled versions of regular tools. The activity includes a worksheet with questions about the tools in the gallery, as well as questions about why we use machines to do these jobs in modern times. The goal is to understand that engineers design robots to do slow or dangerous jobs more safely and efficiently. The worksheet asks participants to think of what jobs may have robots in the future, and how the robots could help. The worksheet asks the participant to draw what they think a robot looks like at the beginning of the activity and then again at the end of the activity. Usually children perceive robots closer to the media

	stereotype, but hopefully by the end the participants will understand that robots are automated machines designed to make work safer and easier.
Age considerations	Instead of asking young children to think broadly about industries that would be aided by automation, the activity could ask them which parts of their life they would rather have a robot do, for example make their bed, or put away their toys. This might be more relatable to young children and thus easier to understand.
Learning outcomes	• Automation makes slow or dangerous jobs easier and faster • Many "real-world" robots are just computerized versions of regular tools

Title/Theme	Shop Like a Roman
Background	There are many examples of coins and currency in the museum's Roman Gallery. The goal of this activity is to get children thinking about how much the pieces might be worth, and how a person in Londinium purchased everyday items.
Activity description	This activity takes the form of a worksheet, similar to those used to teach schoolchildren about counting money. There are illustrations of different types of coins, but they are Roman rather than modern. The value of each coin is specified on the worksheet. The worksheet gives examples of items that a Roman person may have bought (it would be ideal to have the items be clearly visible in the gallery), gives an approximate cost of each item, and asks which combination of coins they would use to buy each item. The worksheet should be long enough to help children think more deeply about a specific topic in a fairly expansive gallery, but not so long as to discourage further exploration.
Age considerations	For children who are too young for the maths aspect of the worksheet, there could be simpler questions asking them to look around the galleries and see which items they might want to buy if they were in Londinium.
Learning outcomes	• Basic maths skills • Looking at an exhibit in a new way: not just old coins, but real money that people used to buy things

Title/Theme	Ada Lovelace Performance

Background	When programming a computer, it is important to use detailed and precise instructions. Computers cannot make assumptions about how to complete a multi-step task, so the programmer must specify each step separately. Many consider Ada Lovelace, the character this performance features, to be the first computer programmer due to her work on Charles Babbage's Analytical Engine. Lovelace was born in London, making her an appropriate choice for the Museum of London.
Activity description	An actress portraying Ada Lovelace takes on the role of a "computer." After presenting some background on Lovelace and basics of computer programming, she asks for audience instruction on completing a simple task. The task itself does not have to be anything in particular, but it must be simple enough for most children to know how to do it while still involving several steps. Possibilities include making a sandwich or preparing tea. Whatever the task, the actress begins by asking the audience what she should do first. Once she receives an instruction, she follows it very literally; for example, if someone tells her to take the bread out of the bag, she removes the entire loaf. This process continues with each subsequent instruction until the actress has achieved the desired results, such as a completed sandwich or a brewed cup of tea. She concludes the performance by comparing what just occurred to the process of computer programming. She explains to the audience that it can be difficult to get a computer to do what you want, but if you can figure out exactly what to say, the results are certainly worth the effort. An alternate version of this performance includes an actor portraying a second character, possibly Charles Babbage, who carries out instructions as the "computer" after Ada Lovelace relays them as the "programmer." This two-actor setup would be more appropriate for a larger audience, which may shout too many instructions at once to practically command an actor directly. Including two actors allows one to concentrate on selecting an instruction from the audience while the other follows the instructions.
Age considerations	Some very young children, aged 5 and under, may have difficulty determining the next step. However, since not every child in the audience needs to deliver instructions for the activity to work, this should not prove a problem as long as there are older children present as well. The activity has elements that appeal to both younger and older children. Older children will enjoy the challenge to produce desired results, while

	younger children will enjoy the comedy when the actress interprets an instruction in an unintended way.
Learning outcomes	• Basic information about Ada Lovelace • The basic thought process, namely the need for specific detail, behind computer programming

Title/Theme	Augmented Reality Activity Trails
Background	This activity can be made to work with any activity trail, but for the purposes of this explanation, we use the simple machines scavenger hunt as an example. There are six simple machines that people have used throughout history to make work easier. These machines are the lever, wheel and axle, pulley, ramp, wedge, and screw.
Activity description	There are numerous simple machines throughout the galleries, and the scavenger hunt worksheet guides participants to examples of each. This activity builds on the worksheet by adding an augmented reality element. Using a tablet or phone with the downloaded app, participants can scan special AR tags near the simple machines in exhibits and see a graphic on the screen that demonstrates how the simple machine is used. The screen will display a three-dimensional image of the simple machine in use in a way that allows the user to view the same graphic from different angles by changing the perspective of the tablet. For example, the exhibit containing the pulley could be used to demonstrate how the Romans would raise and lower the sails in a short animation on the screen of the tablet or phone. Participants who see the simple machine in action will have a stronger understanding of the concept.
Age considerations	The augmented reality aspect of this activity requires basic understanding of tablets. Facilitators could introduce the concepts with a much simpler paper trail guide with checkboxes and finding large examples of simple machines in the gallery.
Learning outcomes	• The uses of simple machines • The persistence of these machines and their uses today

Title/Theme	Fire Pyramid Craft

Background	The Great Fire of London was a massively destructive fire that burned from 2 to 5 September 1666. Though it started as a small fire on Pudding Lane, it quickly spread due to hot, dry summer conditions, strong winds, and the abundance of flammable material throughout London at the time. A fire is the product of a type of chemical reaction called combustion. In order for a fire to start, four factors need to be present: oxygen, heat, fuel (any combustible material), and a chain chemical reaction (the result of energy from one reaction being transferred to further oxygen and fuel molecules).
Activity description	The activity is divided into two parts: the introduction and the craft. In the introduction, the facilitators of the activity provide brief background information about the Great Fire of London, specifically how it started, and the chemistry involved in allowing a fire to start. Specifically, they focus on a construct called the fire tetrahedron (called the "fire pyramid" in the activity), which is an illustration of the fact that four elements are necessary to make a fire. After the introduction, the facilitators invite participants to create their own pyramid by thinking of something in their life that requires four things to make. Exactly what this is can be anything, but facilitators provide suggestions; examples include types of food, a good playground, or even things that are very important to the child (for example, their family, their favorite food, their dog, and football). To avoid requiring the children to use scissors, the activity setup includes pre-cut triangles that they use to make pyramids. Children choose one of many colours of construction paper and write one of the four things that make their chosen object or idea on each triangular face. After decorating the pyramid however they like, they then tape it together so that it makes a freestanding pyramid. The facilitators encourage the children to take home their creation.
Age considerations	Younger children may not understand the introductory portion concerning the chemistry behind fire, but they can still take part in the craft afterwards. It might be beneficial to set up the craft station separate from the introductory portion so families can take part without having viewed the introduction. The concept of a chemical chain reaction may be difficult for young children to grasp. Instead, it may be appropriate to use the fire triangle, an earlier version of the tetrahedron which only included oxygen, heat, and fuel.

Learning outcomes	- Four things are necessary to make a fire: oxygen, heat, fuel, and a chain chemical reaction. - Making connections; applying the concept of the fire pyramid to something else the child is familiar with - Creativity in how children construct and decorate their pyramid