Digital Resources for Teachers

An Interactive Qualifying Project Report
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by

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Abstract

In collaboration with the London Science Museum, our project team developed a digital resource for teachers to link objects in museum galleries to the British National Curriculum. We tested the effectiveness of this type of resource through evaluations of two prototypes on an iPad. After testing and data analysis, we provided recommendations for the Science Museum to move forward with this type of application development. Our results concluded that this type of resource is easy for teachers to use, and it is something teachers are engaged and motivated to use to bring content from the classroom to object-rich galleries in museums.

Acknowledgements

We would like to sincerely thank the Audience Research team at the London Science Museum for their guidance and support throughout this project. In particular, we would like to give special thanks to Hannah Clipson, who guided us every step of the way and made this IQP a truly meaningful and memorable experience. Thanks also to Science Museum staff members Jane Dowden (Learning), Anne Prugnon (New Media), and Grace Kimble (Audience Research) for their guidance and input, without which we could not have achieved such success in our project. In addition, we would like to thank our museum and science center contacts in the U.S., particularly Sharon Horrigan and Maggie Rabidou from the Boston Science Museum. Finally, we would like to extend a special thanks to our advisors, Dominic Golding and Melissa-Sue John for their wealth of understanding, support, and advice.

Executive Summary

The London Science Museum is currently exploring ways to utilize technology to engage school groups. Research conducted by the Science Museum and others reveal that teachers often feel uncomfortable and unprepared to teach their students in galleries that are object-rich—galleries that lack the hands-on and fun factor that students usually crave. In order to solve this problem, the London Science Museum challenged our project team to design methods through a digital resource that would able teachers to create learning experiences for their students in object-rich galleries.

The overall purpose of our IQP was to develop and evaluate innovative interpretation methods for an object activity for use by Key Stage 3 (KS3—students ranging from the ages of 11 to 14) Science teachers, to help them engage their students using mobile technology suitable for an iPad. To do this, our team devised and completed a set of objectives, and developed concept designs and prototypes to interpret four specific, curriculum-related objects in the object-rich gallery *Making the Modern World*. The design of the application was structured to address certain weaknesses of the *Making the Modern World* gallery based on a summative evaluation thereof. The app was designed to focus on four objects from the *Making the Modern World* gallery: Stephenson's Rocket, the Model T Ford, the V2 Rocket, and the Apollo 10 Space Capsule. To develop innovation interpretation methods for the objects our team broke each object down into four sections of content: object information, KS3 curriculum links and information, in-gallery activities, and discussion questions. The prototypes of our iPad application were developed and tested through two rounds of testing with a sample of teachers between May 9 and June 23, 2012. The information we gathered from Prototype 1 testing was used to create Prototype 2. Both prototypes were developed through presentation software and were presented on an iPad using the application Keynote, which emulated the features of an actual iPad application through imbedded hyperlinks and their design. This allowed us to conduct testing as though it were an actual application and strengthened our understanding of the functionality of this type of digital resource.

The app received very positive responses; it was clear that the app is something that teachers want and are motivated to use. Teachers were excited about the prospect of having information and ideas provided at their fingertips and felt that the app would be useful and engaging.

From testing of Prototype 1, which focused on usability, motivation, and engagement, it was found that teachers felt the app was helpful as a museum resource because they felt they could engage their students using it, and they felt the app provided an immense variety in the form of content to stimulate interest. Whilst the majority of teachers skipped or skimmed over the tutorial page included in the application, teachers were able to navigate easily through the application because they felt the design of the app was simple, easy to understand, and easy to use; at the completion of the evaluation, we observed that each teacher confident in using the application: *"It's pretty self-explanatory once you get the hang of it"—KS3 Science teacher.*

The results of this first prototype showed the enormous potential this type of application as a resource to assist teachers in engaging their students in object-rich galleries. Teachers did, however, request some sort of pre-visit information about the application to aid in their comprehension of the app's layout and content; this would allow them to better use the application to engage students while on a school visit: *"It's not only helpful to have the app in advance, it's essential"—KS3 Science teacher*

Prototype 2 was developed based on feedback from Prototype 1 to have a slightly more organized structure and tutorial system to ensure its ease of use and allow teachers to focus their attention on the content and material aspects of the application. The discussion questions were rearranged from their random order and placed in order of difficulty. Prototype 2 was tested through accompanied visits in the *Making the Modern World* gallery with only KS3 teachers. This testing focused on content, engagement, and usability. Because teachers did not have students present during testing, they were encouraged to imagine using the app as though they were with students so that we could hypothetically evaluate student engagement.

Based on the feedback from prototyping, we concluded that the app was an easy to use, engaging tool that teachers are motivated to use. Teachers want this application because it lessens the need to plan material and provides easy access to information. Teachers agreed that the application is very clear and straightforward in its purpose. In addition, it is easy to use and navigate the app such that teachers can access any and all content they wish to use with students. Though there are areas in which this app and the delivering need to be improved before it can be a directed implemented into the Science Museum.

- In taking Prototype 2 to further development, it is very important that it be as simple and easy-to-use as possible to ensure that all teachers, even those who are unfamiliar with touch screen technologies, will not struggle to access the app's content.
  - We recommend that prototype development and testing is a continuous process as the app advances. In this, it is important that the prototype testing occur with school groups (teachers and students) rather than just school teachers.
- Teachers prefer to be able to prepare their lessons in advance in order to develop pre-visit work in the classroom.
  - In order to assist them in doing so and build an understanding of the app's capabilities and content, it is essential that teachers are allowed access to either the entire application or a tutorial and introduction to the application prior to their visit.
- Teachers expressed an interest and need for a greater number and range of activities and discussion questions.
  - More content needs to be added to allow for 'leveling' of the activities, discussion questions, and possibly KS3 visual content. Adapting the application's categories to these levels is critical to allow the app to give teachers flexibility in choosing at which level their students are performing.
  - Similarly, we recommend that the app be expanded to utilize the wealth of objects available in the *Making the Modern World* gallery. In doing this, content relating to more KS3 topics should be developed.
- Teachers want students to have the experience of interacting and making curriculum links with the gallery, but also want to extend to the classroom the lessons learned in the museum.
  - We recommend that additional information or activities are included on the Science Museum website for post-visit sessions in the classroom. Because the students will have more space and supplies in the classroom, we recommend that such activities be more hands-on than those available in the application.

This application and the administration of these recommendations will allow the London Science Museum to have an unparalleled teacher resource for engaging students in object-rich galleries and having them create meaningful learning experiences.

Authorship

Every member of the group contributed equally in this project effort. The writing and editing was divided such that each member did 25% of writing and editing, respectively. Content development was shared such that each member researched and determined the content and relevant curriculum links for one of the four focus objects found in the *Making the Modern World* gallery.

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1. Introduction

Museums, especially science museums, are always seeking new and interesting ways to engage their visitors. By implementing digital technologies within their galleries, museums can provide more interactive and educational experiences for visitors. Technology, particularly mobile technology, is useful in helping engage visitors while retaining the self-directed atmosphere of museum learning and is thus gaining popularity in museums as they seek to create more interactive learning experiences. According to a survey by Tallon (2011), many museums either already use (34%) or plan to use (26%) mobile technologies in their exhibits.

A significant part of the museum visitor demographic is school groups, which use the museum as an opportunity to learn in a freer learning environment than is typically achievable in the classroom. Teachers take their students to museums in order to provide learning experiences that a classroom cannot deliver. While children are attracted to this type of learning environment, it can be difficult for teachers to promote effective student engagement and learning. The implementation of digital technologies has helped museum galleries become more accessible to students of all ages, but there is still more that could be done to help engage students in learning through technology.

The London Science Museum continually strives to create meaningful learning experiences for all its visitors using the timeless artifacts found in its galleries. Yet many school teachers struggle to make object-rich galleries relevant and interesting for their students because they, themselves, may not fully understand the significance of all the artifacts displayed. Teachers may not feel confident in their knowledge of the objects' curricular relevance and can thus struggle to find ways of engaging their students. Consequently, students do not get the full meaning and learning experiences that these types of galleries have to offer. In order to help address this shortcoming, the Science Museum wants to implement a resource to aid teachers in engaging their students in object-rich galleries, as well as to facilitate school group visits; the Science Museum wants to utilize the expanding field of digital technology to create a resource that would be specifically for the use of teachers. Therefore, our project goal was to develop and evaluate innovative interpretation methods for an object activity for use by KS3 Science teachers to help them engage their students using mobile technology suitable for an iPad.

Many studies have been conducted on school groups in museums and on the use of digital technologies in museums; but less research has been conducted on the use of hand-held digital technologies by teachers in museums. By determining through research what teachers want and need from a digital museum device, it will be possible to alleviate a significant amount of teacher stress before, during, and after a museum visit and thus allow the teacher to focus primarily on the learning experience of the students. The success of this technology in the hands of teachers can not only create meaningful school group visits, but even encourage more future visits by school groups. Accordingly, the objectives of this project were: to investigate the role of digital technologies in museums both in general and from a teacher's perspective; to develop a prototype mobile digital resource for teachers to use in facilitating meaningful learning experiences for their students in an object-rich gallery; to evaluate the resource to gauge its success and make necessary revisions; and to provide recommendations to the Science Museum.

To achieve these objectives, the team conducted an extensive review of the literature and carried out supplemental interviews with teachers, staff members of the London Science Museum, and experts in fields such as education, digital technology, and museum management. This process developed as new resources were discovered through both formal and informal in-person interviews, observations, and surveys. The outcomes of this research allowed us to clarify the goals, objectives, and limitations of the Science Museum regarding the iPad application and, in doing so, develop concepts for the prototype. Once a rudimentary prototype was developed, we gathered teacher feedback through onsite interviews as well as pre and post-visit surveys. Throughout this process we also continued to collect sponsor feedback on the progress of the application and apply changes when needed. Following the development and testing of the prototype iPad application, we concluded with a set of recommendations regarding the continued development of the application.

2. Literature Review

This review is a summation of the literature researched in the areas of digital technologies, teachers, and museums, to best encapsulate the progress of these areas and their relation to the Science Museum. The Science Museum in London is one of most popular museums in the world and is dedicated to furthering scientific knowledge and exploration. With a consistently large flow of school group visitors and a successful history of producing learning resources for science teachers to use in classroom, the Science Museum has now put a new emphasis on producing learning resources to be used on the museum floor, such as the *Making the Modern World* gallery. The Science Museum plans to achieve this through innovative digital methods, such as mobile interpretations, to genuinely aid teachers in engaging their students with the objects in their galleries and exhibitions (McSweeney, 2011). The literature review describes the nature of this progression in the following manner:

1. *Changes in museums due to technology*—this section describes how museums aims and missions have changed to incorporate advances in technology;
2. *Learning in museum environments*—based on changes in technology, this section describes how museums try to maximize learning in their galleries;
3. *The Science Museum, London*—in a combination of the previous two parts, this section portrays how the Science Museum in London has adapted to changes in technology and maximized learning in its galleries;
4. *Teachers use of digital technologies and museums*—this section describes how teachers use museums and technology to engage their students in learning; and,
5. *Teachers and technology in the 'Making the Modern World' gallery*—as a compilation of the preceding sections, this part describes how the London Science Museum wishes to use the latest technological trends to aid teachers in engaging their students in the museum, specifically in the *Making the Modern World* gallery.

2.1. Changes in museums due to technology

A museum may be described as a permanent institution for the service of society, but its service is ever-changing. One of the main causes of change is, of course, technology. In order to contend with the ever-expanding array of knowledge accessible through technologies, many museums have incorporated digital technology into their exhibitions and galleries. As stated by Din and Hecht (2007) in *The Digital Museum: A Think Guide*, "The presence of digital

technology in museums is both pervasive and permanent. While the actual technologies continue to morph, museums will continue to adjust to both the promise and the challenge inherent in digital media." It was originally feared that the addition of technology would replace the physical objects, but instead it has been discovered that technology enhances visitor understanding of the objects through interactive interpretation. Digital technologies facilitate established kinds of activities and create some which would not otherwise be possible (Hawkey, 2004). Museums are moving toward an object-based discourse, in which meaning is conveyed through the integration of object, display, and visitor narrative (Eberbach, 2005). Current museums are designed to encourage exploration and conversation about an object, rather than just observation. Instead of being forced to view a gallery through the eyes of its creator, visitors can, especially with the aid of digital technologies, create their own learning by making personal connections (Hawkey, 2004). According to Borun (2002), more traditional learning structures should not be the focus of museum learning, but rather more social, object-based group interactions. By moving beyond object-centered exhibitions, visitors can create meaningful experiences through connecting an object to real life.

2.1.1. Shifts with changing technology

Digital technologies have helped museums develop more interactive experiences. Digital technologies have been a part of the museum landscape since at least 1952 when what might have been the first audio tour was introduced at the Stedelijk Museum in Amsterdam using radio broadcast technology (Proctor & Burton, 2011). These first types of digital technologies became widely used and allowed a visitor to move more at his/her own pace and provided more in-depth information on particular exhibits or artifacts. "Other than audio tours loaned out on made-for-museum devices, podcasts are probably the most common mobile media being published by museums, alongside other downloadable content ranging from PDF's to eBooks and videos" (Proctor & Burton, 2011). Likewise, the creation of museum websites now allows constant access to museum learning. These primary digital technologies were the first steps towards museums that use digital technologies to encourage and engage students of all ages. As seen in Figure 1, there are now many digital technologies, both on and off-site, that offer visitors another way of engaging with the museum.

Currently, the latest technological swing sweeping through museums is the move from one-way broadcast delivery systems to two-way communication models through networked

mobile devices (Proctor & Burton, 2011; Smith, 2009). While one-way broadcast delivery systems, like audio tours and websites, only move information from museum to consumer, two-way broadcast technologies allow more back-and-forth interaction between these two systems. Audio tours are limited to teaching solely through the sense of audio, whereas mobile devices like the iPod Touch and the iPad allow for learning through auricular senses as well as other sensory triggers such as touch and sight.

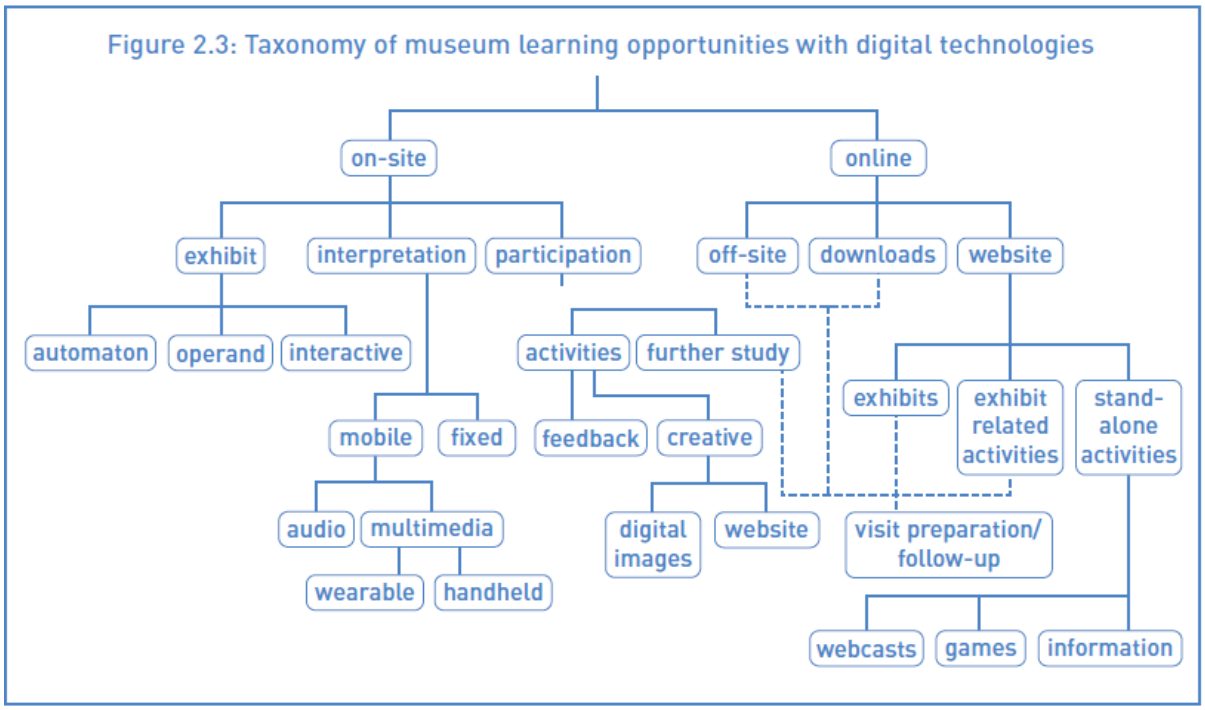

Figure 1: Taxonomy of Museum Learning Opportunities with Digital Technology (Hawkey, 2004)

2.1.2. Shifts with audience attraction

With this latest technological shift, museums have increased their focus on ways to attract larger and more diverse audiences. "New emphasis is placed on museum-audience interactions and relationships" (Gilmore & Rentschler, 2002). As a result, the following four main objectives were identified by Tallon (2011) as reasons researchers/vendors believe museums are considering mobile technologies:

1. To experiment with engaging visitors;
2. To create a more interactive experience;
3. To attract new and more diverse groups of visitors; and,
4. To provide better access for visitors with special needs.

Ultimately, museums seek new and innovative methods such as mobile interpretations to satisfy the needs and wants of modern visitors. Museums have shifted from being an institution traditionally being focused on gathering, preserving and studying to an institution where audience attraction is a main focus (Gilmore & Rentschler, 2002). Mobile technology within a museum not only attracts more visitors, but also introduces new visitor types to a museum such as students and children. Where some exhibits may be beyond the understanding of a young visitor, digital technologies serve as a mediator of information, facilitating understanding such that even young visitors can connect with and learn from a gallery or object. "As museums are part of the not-for-profit sector and depend on government for up to 70 percent of their income, they must be seen to offer value to the government by attracting increasing visitor numbers" (Gilmore & Rentschler, 2002). It is possible that governments now see museums as educational environments for more and more young visitors. Many modern museums have shifted toward to becoming a secondary supportive learning institute for schools and classrooms. For example, the London Science Museums website says that the museum serves as an informal learning institution to aid the formal education system of London (Science Museum, "About us," n.d.).

While digital technologies of all sorts are being more widely used for various reasons in museums, a recent survey shows that larger rather than smaller museums use or plan to use mobile digital devices (Figure 2). This may be because larger museums believe that mobile technologies will enhance the visitor experience and/or they have the resources to support these devices while smaller museums do not.

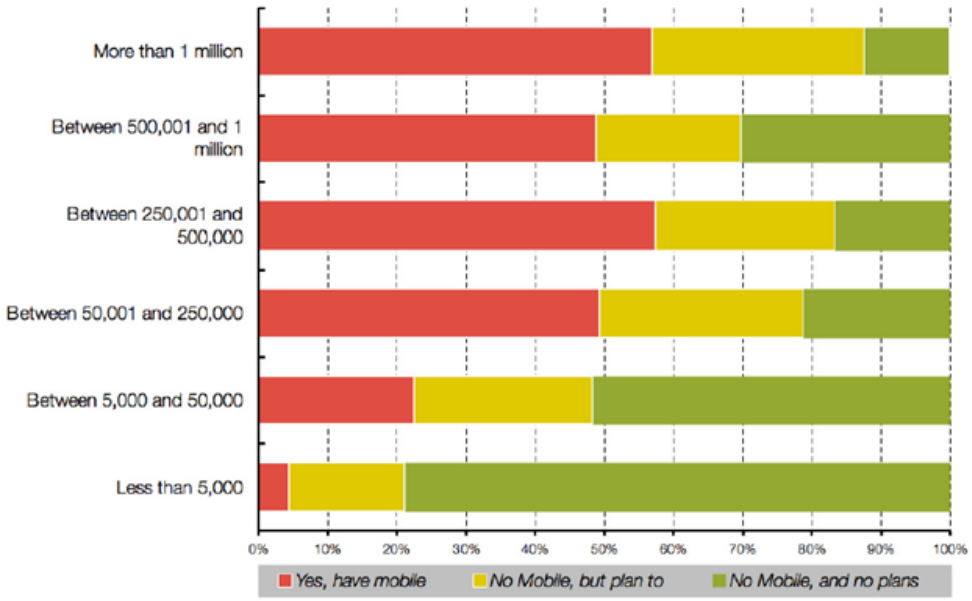

Figure 2: Graph depicting usage of mobile interpretation tools vs. annual visitor attendance (Tallon, 2011)

2.1.3. Shifts with uses of technology

One of the most influential technological innovations now used in museums and mobile devices around the world occurred in 1965, when E.A. Johnson presented his idea of developing a touch screen and stated the potential of this device to be a "very efficient coupling between man and machine." In recent years, the technology of touch screens has been refined so that they have become intuitive, engaging, and commonplace in museums and elsewhere. This is one of the reasons and examples why museums choose digital resources as an aid in audience attraction, for they have become an enormous potential as learning facilitators (Hawkey, 2004). Digital technologies provide an interactive platform for the visitors and exhibitions; as a matter of fact, Tallon (2011, pp. 22) found that the dominant reason why science & technology museums use digital resources is "to create a more interactive experience." The broad variety of digital technology available for use by museums has expanded this horizon such that technology can create an interactive visitor experience even when the visitor is no longer on-site, as shown in Figure 1.

In *Interactive Learning in Museums of Art and Design*, Marianna Adams and Theano Moussouri (2002, pp. 11) conclude that a successful interactive space in a museum should promote:

1. Multi-sensory dialogue, exploration, and discovery;
2. Cultural connections;

3. Empowerment;
4. Uniqueness; and,
5. Construction of meaning.

Each of these features helps facilitate a 'memorable and unique' experience for museum visitors, especially for science museums because they are "by their very nature and original mission interactive" (Adams & Moussourri, 2002). Mobile interpretations, too, can be used to construct meaning and connect visitors to an exhibition.

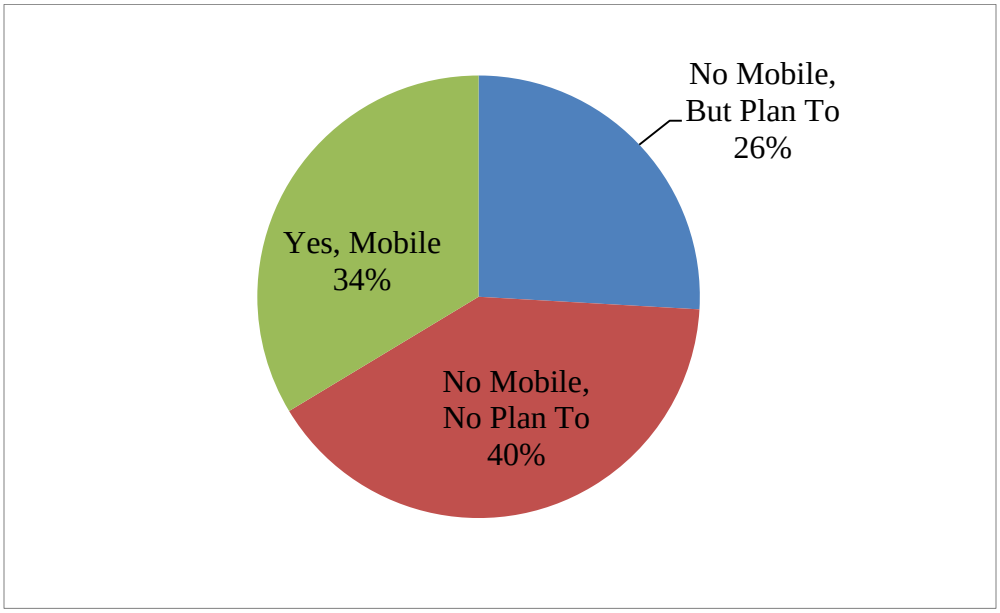

Figure 3: Distribution of mobile technologies throughout museums (Tallon, 2011)

A survey conducted by Tallon (2011) found that 60% of the participating museums either already have or plan to offer mobile interpretations in their institutions (Figure 3). Among museums currently offering mobile interpretations, 76% offered audio tours which were the most popular mobile interpretation tools in use. Tallon's survey (2011) also predicts that the top three most anticipated digital resources that will be implemented in the next three years include:

1. Increased in-house content development (69% of respondents);
2. Web sites optimized for mobile devices (55%); and
3. Smartphone applications (46%).

Already this is evident with the increasing popularity of iPods, iPads, and mobile web applications. Yet, these technologies are of no use if they cannot provide the basic platform of learning that is essential in museums. As technologies have become central to the mission of 21st century museums, museums implement new technological approaches and methods to become a

secondary supportive educational institute to formal schools that provides the old-fashioned school curriculum (Hawkey, 2004). As Hawkey (2004, pp. 2) says "Lifelong learning, museums, and digital technologies share many of the same attributes, with emphasis on learning from objects (rather than about objects) and on strategies for discovering information (rather than the information itself)."

2.2. Learning in museum environments

Museums provide a learning environment which, unlike traditional classroom learning, allows visitors to move at their own pace and learn about their particular interests. This type of learning is both self-directed, meaning the student takes responsibility for his/her own learning, and informal, meaning that there is little formal structure to how knowledge is acquired by the student (Gammon, 2003). This lack of structure in a learning environment is a stark contrast to the concept of "traditional" learning. Rather than the individualistic nature of the classroom, people are able to learn in a group, which allows for visitors to experience and learn with and from one another. In this way, an object or artifact can spark a conversation that carries an educational as well as a social component. Interactive exhibitions are especially useful for this because they tend to promote more personal connections where the visitor can choose what material he/she would most like to learn about. This material can then be shared through conversation and interaction with other visitors (Borun, 2002). However, before the implementation of interactive digital technologies in museums, such a connection was limited to galleries that were specifically designed to be physically interactive. Although the museums had freer, self-directed learning environments, information was often conveyed in a didactic manner similar to the classroom setting by providing facts to be read and memorized from text panels. With the implementation of technology, museums, even object-rich galleries that were not originally designed to be interactive, can promote constructivist learning, in which visitors create meaningful learning for themselves. In modern museums, the interactivity provided by many digital technologies allows for connection not only between visitors, but also between the visitor and the museum itself. As shown in Figure 1, technology plays a role not only within museums themselves, but also off-site. Using digital technologies, museums can attract and engage visitors from all areas.

Although digital technologies have shown excellent potential to connect visitors to the museum and each other and engage them in learning, museums must maintain a balance between

educational philosophies, with the possibility of catering to more than one style of learning. Museums can lend themselves to either passive transmission of knowledge from teacher to student—a passive philosophy—or to a self-directed, exploratory form of learning—an active philosophy (Castle, 2001). The passive philosophy of learning tends to have the structure needed for larger groups, particularly school groups. It is for school groups in particular that museums must balance their use of digital technologies, which provide learning freedom, with the structure that teachers require in managing groups of children. Similarly, museums must accommodate teachers' desire for curriculum relevance in museum galleries. In a study done by TW Research, curriculum relevance was ranked by the majority of teachers as the most important reason for visiting a museum (TW Research, 2007). Yet the lecture atmosphere of a traditional classroom setting is seen by museum staff as ineffective, believing that a more active philosophy of learning is more appropriate for the museum setting (Castle, 2001). Rather than memorizing a set of facts or theories, students should be encouraged to take initiative towards their learning by "…[C]onstructing an understanding, relating new experiences to existing knowledge" (Sharples, 2003). It is here that digital technology could serve to bridge the gap between the structure of the classroom environment and the free-choice environment of the museum. It would bridge the gap by helping teachers become the interface between factual knowledge and engagement and exploration. As digital technology in museums has evolved, there have been many different opportunities to use technology to engage visitors in learning (Figure 1), but most technologies currently in use are created to serve the needs of individual visitors. Thus, a tool that caters to the individual needs of educators is invaluable for engagement of school groups in learning and for the ease of the teachers.

2.3. The Science Museum, London[1]

The Science Museum in London does its best to promote learning within its walls as its overarching purpose since its inception has been technical education. However, beginning in the 1960s, the emphasis of the museum started to shift more towards preserving historical artifacts and educating visitors about them and their social context. This new approach was implemented through the development of exhibitions in which visitors discover how things work interactively with their hands rather than passively by reading exhibit descriptions. One of the most popular of

[1] For a complete description of the London Science Museum, its history and mission, see Appendix A: Sponsor Description

these galleries has been the *Launch Pad* which first opened in 1986 (Science Museum, "Museum history," n.d.). Still throughout all its changes, as the UK's most popular destination dedicated to science, technology, engineering, medicine, design and enterprise, the Science Museum has maintained its mission to help its visitors make sense of the science that helps shape their lives. The museum serves its purpose to play an integral part in changing the world's relationship with science and technology (Science Museum, "About us," n.d.).

2.3.1. Adapting to time

Technology has changed dramatically since the Science Museum's inception in 1857 and the Science Museum strives to build exhibitions that reflect these changes while at the same time incorporating new technologies as interpretive devices. As noted in the "Museum History" (n.d.) section of its website: "The history of the Science Museum…has been one of continual change. The exhibition galleries are never static for long, as they have to reflect and comment on the increasing pace of change in science, technology, industry and medicine." Once again, we can use the *Launch Pad* gallery as a perfect example of this adaptive nature of the Science museum. The *Launch Pad* gallery first opened in 1986 as a means to help visitors, especially children, understand the way things work through hands on interaction (Figure 4). More recently in a 2007, an entirely new *Launch Pad* (Figure 5) gallery was opened, emphasizing the shifting nature of the museum through time (Science Museum, "Museum History," n.d.).

Figure 4: Children interact with the 'Train Wheel' exhibit in the 'old' *Launch Pad* ("Untitled," n.d.)

Figure 5: Children interact with the 'Train Wheel' exhibit in the 'new' *Launch Pad* (Children, n.d.)

2.3.2. Adapting to technology

The Science Museum has also adapted to digital technology with its interaction through social media—starting with its joining Facebook on December 9, 2007 (Science Museum, "In Facebook," n.d.) and also with its joining Twitter—and most recently with its addition of an IMAX theater in 2011 (Fletcher, 2011) the largest in Europe. The Science Museum has its own Audience Research and Advocacy Group designated to design interactive and mobile exhibitions using digital technology. The Audience Research and Advocacy Group works alongside project teams to ensure that learning and audience understanding is integrated within the project at three main stages of development (Science Museum, "What do we do?" n.d.). These three stages are:

- *Front End Evaluation*: conducted at beginning stages of a project to help define the target audience and set realistic objectives for the project;
- *Formative Evaluation*: conducted at the development stages to help improve the effectiveness of project. This aims to remove potential ergonomic, motivational and intellectual barriers that the project may have; and,
- *Summative Evaluation*: conducted at completion of project to evaluate the extent to which the project has met its objectives and identify the successes and failures of the project for future reference.

These groups have added to the list of digital resources available in museum, or through its website, in audio tours, interactive exhibits, as well as a vast number of game products. One such

product (Figure 6) uses augmented reality technology and was debuted with the opening of the *Atmosphere* gallery in 2010 (Brown, 2010).

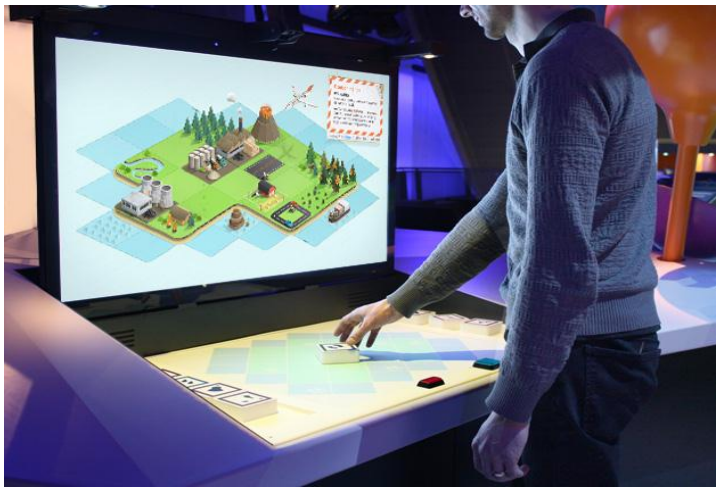

Figure 6: Augmented reality being used in the Science Museum (Atmosphere, n.d.)

The Science Museum's use of augmented reality technology demonstrates its adaption to the latest technological swing sweeping through museums—the move from one-way broadcast delivery systems to two-way communication models. The Science museum is currently looking for more ways to implement two-way communication models through mobile phones, iPods, and iPads. In 2009, the Science Museum tested an iPod Multimedia Guide to provide new interpretation methods to overcome barriers to visitors' engagement with objects in the *Making the Modern World* gallery (Teixeira, 2009). In Teresa Teixeira's (2009) summary of the testing, she reported that the main findings were positive with regards to the interaction between the device and the visitor(s) and that device allowed people to be flexible in how they chose to traverse the gallery. Testing also showed that improvements need to be made in the following areas before a real device can be fully implemented in the gallery:

- *Orientation*: including a feature that would allow visitors to avoid getting lost or disoriented while using the guide;
- *Awareness*: making visitors aware of the guide and making it easily accessible;
- *Motivation*: motivating users to take advantage of the iPod guide in their exploration of the gallery;
- *Use by groups*: enabling the device to accommodate large groups rather than one to two people; and,

- *Number of objects*: testing the number of objects a device can support without surpassing the threshold of "too much."

These recommendations have aided in the development of the Science Museum's most recent uses of mobile technology: the development of a trail for the popular SCVNGR application, and the development of a mobile application called the James May App.

SCVNGR is a game that involves completing challenges at different places or stations in the museum; the Science Museum designed a trail for this mobile app that provides a list of challenges that are geared toward specific objects in the many galleries in the museum. The aim of this app was to increase visitor engagement and interaction with the Museum's objects (Hobson, 2012). Marie Hobson (2012) summarizes in her report found that there is a positive need and increasing demand for more interactive and learning activities such as SCVNGR, where visitors engage and learn about the objects. One of the most recent products created by the Science Museum is the James May App, which combines augmented technology with mobile devices. In this app, James May, a renowned TV presenter and science enthusiast, serves as a personal tour guide for objects in the *Making the Modern World* gallery (Science Museum, "James May brings science to life," 2012). Through these mobile applications and other projects, the Science Museum is now very aware of the benefits and limitations this type of technology in its galleries. The museum is examining this technology further to create a digital resource specifically for teachers' use specifically to help them create meaningful learning experiences for the museum's most popular audience—students (McSweeney, Clipson, & Prugnon, 2012).

2.3.3. Interacting with teachers through technology

Many studies of the interaction between museums and school groups/teachers have been conducted by the museum community, and by the Science Museum itself (Frankly, Green, & Webb, 2010; Hobson & Robinson, 2010; McSweeney et al., 2012; TW Research, 2007; Wishart & Triggs, 2010) to better understand how the two can work together to maximize learning. The engagement of the teachers' curriculum plays a large role in the attendance of school groups to the Science Museum. Unlike most other audiences that the museum attracts, teachers visit the museum more for educational rather than recreational reasons. A teacher's visit to the museum with a school group tends to be an annex to classroom learning; the museum provides educational experiences that cannot be provided in the classroom. According to the museum's

webpage, “Facts and Figures” (n.d.), the Science Museum welcomes over 2.7 million visitors on average each year, 13% of which come as a booked school group (Figure 7).

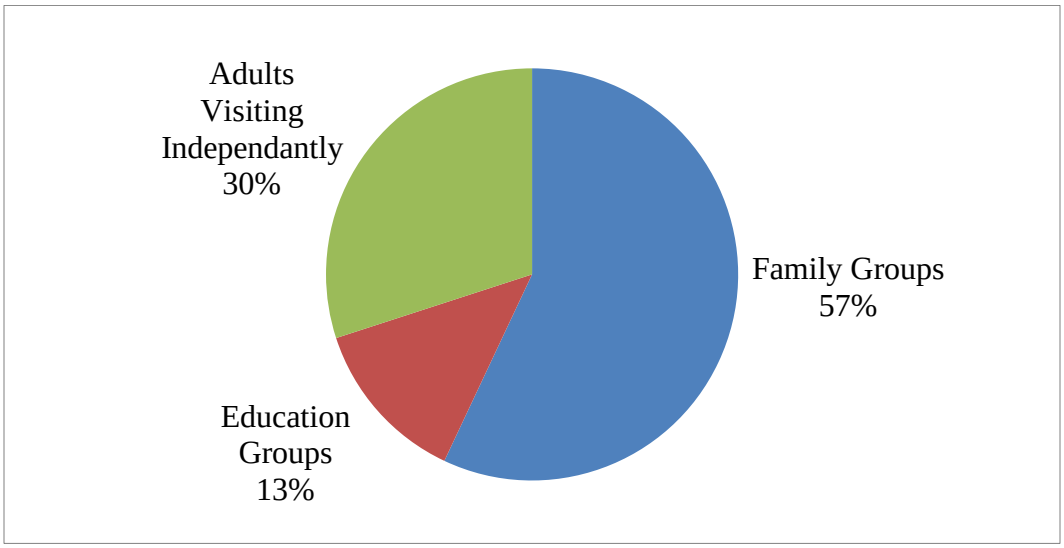

Figure 7: Group demographics of science museum visitors (National Museum of Science and Industry [NMSI], 2011).

From the accounts of the NMSI (2011) from 2010-2011, the number of visits from children under the age of 16 reached over one million with 1,074,128 visits; 700,000 people participated in Science Museum’s learning activities; 11,077,629 people visited the museum’s website; and 367,470 visitors came to the Science Museum in booked education groups, as it remains as one of the top science museum destinations in the world (Figure 8).

In the Science Museum and all over the world, a new emphasis is being placed on producing resources that teachers can use. Digital resources are being developed in an attempt to engage teachers and their students in object-rich galleries and enrich the experience at the Science Museum. Through innovative methods and new digital technology, researchers and developers aim to address the varying needs of the teachers while genuinely engaging students in the presented objects (McSweeney et al., 2012).

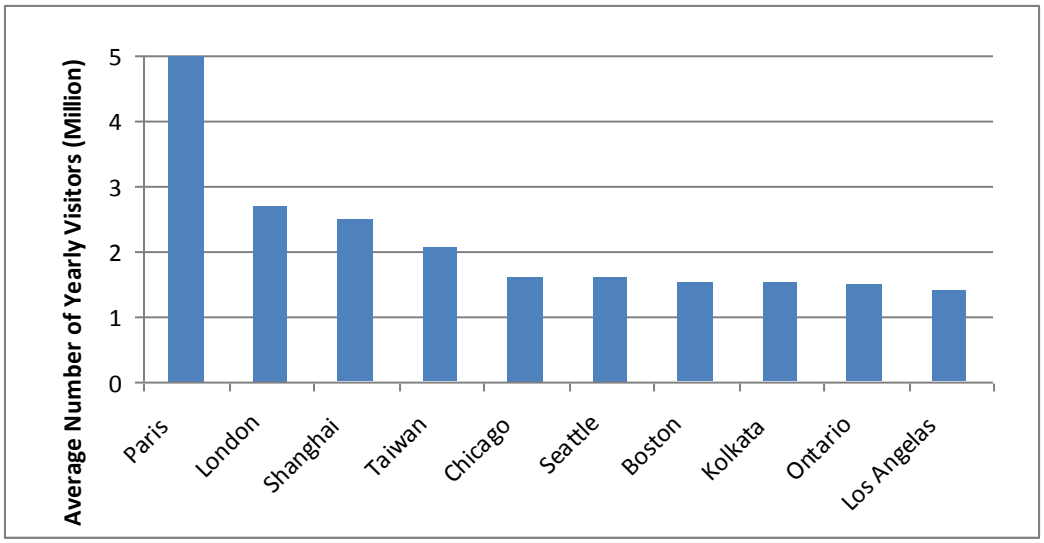

Figure 8: The 10 most visited science centers worldwide (Walhimer, 2012).

2.4. Teachers use of digital technologies and museums

One of these main needs teachers have is for mobile digital technology that can guide and prepare them to embark upon object-rich galleries. These findings come from observation that teachers, like most visitors, often feel overwhelmed while walking through galleries without guidance (Frankly et al., 2010). Staff members at the London Science Museum have also observed that teachers regularly feel uncomfortable and unprepared to teach their students in these object-rich galleries (Frankly et al., 2010; TW Research, 2007). Teachers generally feel more confident when they are given some direction as to how to engage their students and create meaningful learning experiences. A mobile device would be able to provide teachers the resources and reassurance they need to operate in these types of galleries, where it is nearly impossible to teach otherwise. Unlike most digital technologies, the target audience for digital technologies for teachers is very small and specific. Therefore, it is important to understand how teachers utilize museum technology in correlation with the National Curriculum and how digital resources are made to meet their needs.

2.4.1. Use of museums

Gammon and Siems (2001) have found that teachers visiting a museum with their class emphasize the following:

- *Information*: prior to the visit, teachers need to know what is on display in the exhibitions they are visiting so they can link the curriculum to the visit;

- *Take-home work*: after the visit, teachers need something to remind their pupils of their visit for follow-up work in the classroom; teachers are particularly keen on things that their pupils can take back to school and use in subsequent lessons; and
- *Student retention*: teachers want their pupils to have clearly and demonstrably gained something from their visit.

In a typical classroom, teachers base their daily lessons on a structured plan that solidifies the concepts, demonstrations, and activities they need to accomplish with their students in a short amount of time. Outside the classroom, they need this same structure. Gammon and Siems (2001) claim that nearly all teachers believe what children gain from an exhibition is determined by the structure of their visit. While students are intrinsically fascinated by museums and their displays, they often do not take the time or the effort to learn unfamiliar concepts on their own. Without structure, they tend to drift from one object to another, briefly gazing at an object or two, and then meeting up with friends. This is especially true in object-rich galleries, such as the *Making the Modern World*, rather than those that are interactive and generally more stimulating to children. Students often need an interesting, engaging way to learn in a museum that doesn't require a lot of tedious reading which they may not understand, as "it cannot be assumed that children will be able to be able to put the objects in a context as easily as adults" (Gammon & Siems, 2001).

For this reason, many diverse resources are becoming available for teachers to structure their museum visits. Because there are many types of resources accessible to teachers, the ways they use these resources vary greatly. With different options at their disposal, teachers often choose what is most comfortable for them. If teachers are not comfortable with new technologies, such as iPods, iPads, web applications or other digital resources, they are less likely to use them. Instead, they will use worksheets or brochures that are provided by the museum online or in person. Some teachers even believe that using any outside resource takes away from the museum itself, which makes it difficult to introduce them to new resources (Hobson & Robinson, 2010). Those that employ worksheets and brochures commonly use them for pre-visit preparation and post-visit discussion and review, but they may have a difficult time finding a relevant resource to use while at the museum.

A digital resource to be used specifically by teachers in museum exhibitions would provide structure and guidance for their visit, allowing them to focus on teaching to their

students rather than on concerning themselves with other worries like trip logistics. A digital resource, if designed accordingly, can offer structure for museum trips by providing teachers with easy access to museum maps, suggested routes, estimated duration of activities, and more. With all of this information in one place, teachers can spend more time enjoying the museum and its educational benefits rather than trying to find different resources to plan the trip. To fully take advantage of the capabilities of a digital resource, aside from aiding logistical planning, the resources need to be catered to the needs of both students and educators. To characterize which requirements teachers typically look for in a digital resource, it is helpful to look at the challenges they face within the museum and what they may need in an outside resource to overcome these challenges.

2.4.2. Use of museum resources

There are many constraints for teachers visiting museums with their students, and this greatly effects how they use museum resources. Teachers are unlike typical visitors at museums—they require materials that cater to their needs as educators as well as their personal capabilities to handle new technology. In general, teachers of primary and secondary levels call for four basic requirements. In order for resources to be useful for teachers, they should:

1. Have explicit links to the National Curriculum;
2. Be adaptable to suit the teachers' needs;
3. Be understandable for all students of different learning abilities; and,
4. Be of high quality appearance (Hobson & Robinson, 2010).

Within the resource, there needs to be reliable, updated information which is presented in a way that is easily accessible and simple to navigate (Hobson & Robinson, 2010). Because of a lack of time and funding, instructors want resources that can be used without any previous knowledge of the application, gallery, or objects within the gallery, and that can be applied to the situation without any other equipment (Gammon & Siems, 2001). Providing quick, accessible information about an object and its curriculum ties is essential for teachers in charge of school groups, and an innovative, user-friendly digital interpretation is a modern way to bring museums and classrooms together.

Because children do not become engaged in the same objects as adults or in the same manner, it is essential that digital resources meet the needs of both the educator and the students. It is often difficult for teachers to convey essential information to students through static displays

behind glass because the interpretation provided by the museum has in the past typically been text-based, therefore unappealing to pupils and sometimes too advanced for their age group (Gammon & Siems, 2001). This was stated in reference to previous methods used in museums in contrast to the possibilities offered by digital interpretive methods, showing how digital resources have the potential to better engage the students in museums. Using a technology-based resource is an opportunity to engage students as well as aid teachers in communicating important lessons. Museum trips are made to give students new experiences they could not otherwise have in a classroom, so teachers are not looking for a classroom exercise replicated in the museum or a digital version of a worksheet (Frankly et al., 2010; Gammon & Siems, 2001). While worksheets, quizzes, and brochures can be effective ways to teach students in a museum, new technology can bring dull subjects to life, grabbing a student's attention and inspiring him or her to learn more independently. With an increasing pressure on time and money, museum trips are becoming major undertakings for schools and every visit by a school group needs to be demonstrably worthwhile. By utilizing digital resources as guides, educators hope to lead discussions and activities that will engage their students and further spark their interest in important subjects. The pre-planning that is usually required of teachers bringing school groups to museums is one of the primary causes of teacher stress surrounding museum visits (TW Research, 2007). A digital resource could serve to relieve some of this stress by providing the information about a particular exhibition for a teacher, rather than him/her guessing as to curriculum relevance.

2.4.3. Use of digital museum resources

Though research has been conducted on the implications of digital resources, especially in the London Science Museum, much of the research has focused on the general visitor population. Teachers and their students are a specific category of visitors that seek different outcomes and goals from a museum. Hooper-Greenhill (2009) found that teachers have high expectations that museum visits will 'open' their students up to learning.

One way the Science Museum has done just that is through the recent development of a 'mystery object' trail for students to use in the *Making the Modern World* gallery (McSweeney et al., 2012). This idea was developed into a PowerPoint presentation for teachers which shows partial images of different objects throughout the gallery and includes clues for students to guess their identity and location within the exhibition (*Making the Modern World* Deutschbank trail,

n.d.). After each object is 'discovered' teachers can access summaries of what the museum expects students should take from their discovery. When this theory was applied, the *Making the Modern World* gallery was enhanced by an interactive activity, giving students another opportunity to be engaged in the objects.

Though this example of digital technology engaged both the teacher and the museum, it allows little flexibility in the teacher's use of the National Curriculum. To create an effective resource, it is essential for the teacher to be in control of the resource, rather than for the resource to be in control of the teacher. It is also essential to look at the needs of teachers and the ways in which England's secondary school curriculum connects to the objects in the museum's galleries.

2.4.4. Use of curriculum frameworks in museums

Schools in the UK are required to cover several areas in their curriculum, many of which are linked directly to science and technology. Because many of the subjects relate to various exhibitions in the London Science Museum, it is no wonder that out of the 2.7 million visitors in the Museum every year, around 380,000 come as part of a booked school group (Science Museum, "Facts and figures," n.d.). Using the goals of the National Curriculum, the Science Museum attempts to make connections between what is learned at school and what can be learned in its exhibitions. Understanding scientific concepts gives students the ability to link real world experience to theories they are taught in class, improving their critical and creative thinking techniques (Department for Education, 2007).

With the background knowledge specified by the curriculum, students should be equipped to understand the different scientific principles that are seen throughout the galleries. While a majority of teachers are more than capable of teaching many topics, it is impossible for them to know all of the relevant information pertaining to a wide array of museum objects. In this regard, Gammon & Siems (2001) noticed teachers often struggle with the following:

- Issues that are not directly relevant to their pupils lives;
- Subjects that are difficult to illustrate with real examples;
- Topics which were not taught to teachers when they were in school or which have changed in recent years;
- Subjects where they find it difficult to understand the underlying principles; and,
- Topics that are disparate and do not have a clear focus.

The resource teachers are given should eliminate these uncertainties, giving teachers access to relevant information quickly and easily. This will allow educators to readily promote discussions within the group and elicit educated responses from their students about the items before them. This interactive and engaging education style is what justifies the cost and time needed to coordinate a school trip, and it demonstrates how necessary it is in a child's learning (Gammon & Siems, 2001). However, it is important to remember that although the information within the resource should be relevant to the National Curriculum, it should not be overly constrained by it (Gammon & Siems, 2001). A balance must be maintained between structures that support and guide students and the freedom to create a personal learning experience (Frankly et al., 2010). If these guidelines can be followed when creating a museum resource then the goals of the National Curriculum will be met. With this, students will be given opportunities to better their education and interest in learning independently, as well as making science a part of their everyday lives.

2.5. Teachers and technology in the *Making the Modern World* gallery

Presently, the Science Museum is especially interested in developing a digital resource to help teachers—Key Stage 3 (KS3) teachers specifically—interpret the *Making the Modern World* gallery. A Key Stage 2 teacher in a focus group stated that the *Making the Modern World* gallery is a place where science and history come together—a good opportunity to use a cross-curriculum "science in action" approach (Gammon & Siems, 2001). It has been shown however, that KS3 teachers have difficulties finding connections between the materials they must teach their students and the objects available within the gallery. This added effort causes many of these teachers to avoid the *Making the Modern World* gallery in hopes of finding other galleries that more explicitly apply to their syllabus (Gammon & Siems, 2001). To encourage more KS3 teachers to visit this exhibition, the museum believes a digital resource will bridge the gap between the objects in the *Making the Modern World* gallery and the National Curriculum.

Ben Gammon and Jo Siems (2001) have already conducted extensive research in the gallery in terms of teacher/student learning, interaction, and reaction and make several recommendations for change in their report, *Making the Modern World: Summative Evaluation*. From the types of learning that they decided to test in the gallery, they determined that cognitive and affective learning are the most important factors leading towards a meaningful experience in the *Making the Modern World* gallery. In our focus with school groups, we need to concentrate

on cognitive and affective learning to create the most meaningful learning experience for students.

Before learning can occur, the audience must understand the purpose of the gallery. From their evaluation, Gammon and Siems (2001) determined that the main themes of the exhibition are too subtle and often missed; for example, only 45% of the surveyed visitors realized that gallery is arranged in a chronological fashion. Visitors also commented that the exhibition seemed to be geared more towards an adult audience. This is evident in their observation that school groups spent the least amount of time in the gallery compared to any other type of visitor. School groups and young children with their parents spent an average of 5 minutes in the exhibition while the average time spent by all visitors was 10 minutes (Gammon & Siems, 2001). Some of the teachers surveyed reported that the *Making the Modern World* gallery would be impossible to navigate with school groups without first visiting the gallery themselves and creating appropriate lesson plans; "…what children gained from this exhibition would largely be determined on the structure of the visit" (Gammon & Siems, 2001).

With nearly 1800 objects in the gallery covering 250 years of scientific, technological and medical innovations, it is understandable that the *Making the Modern World* gallery can be overwhelming. Although the gallery contains items of both scientific and cultural significance, such as the Apollo 10 Space Capsule, the objects' connection to school curriculum is often unclear for teachers. For the *Making the Modern World* gallery in particular, a digital technology tool would be useful to allow teachers to see how artifacts in the gallery connect with the age-appropriate curriculum, as well as to help the teacher find engaging ways for the students to learn the science behind the artifacts.

A drastic change from museums in the past, current museums promote accessibility of knowledge and life-long learning. In order to accomplish this, as well as to keep up with the modern generations, museums continue to integrate new technologies, providing visitor engagement opportunities that better impart the information available. Although it was originally feared that such technologies would make museums themselves obsolete, they rather encourage the creation of unique museum experiences in which the visitor can control his or her own learning. Museum galleries like *Making the Modern World* are designed to be learning opportunities for visitors of all ages, but adapting to all learning styles is essential. In this way, digital technologies serve as a mediator, making the wealth of knowledge available from a

museum gallery accessible to the interests and abilities of a particular visitor demographic. Through our research into technology, learning, and their roles in the museum setting, as well as extensive testing, we developed a tool that helps museum knowledge be more accessible to school group audiences.

3. Methods

The overall purpose of our IQP was to develop and evaluate innovative interpretation methods for an object activity for use by Key Stage 3 (KS3—students ranging from the ages of 11 to 14) Science teachers, to help them engage their students using mobile technology suitable for an iPad. This object activity was presented in the form of an application that allowed these teachers to engage their respective students in learning in the museum's *Making the Modern World* gallery. Using research and studies provided and performed by the Science Museum and other institutions, we were able to determine how an iPad application could be best be tailored to the needs of teachers while in the museum and thus determine how to bridge the gap between objects and teachers. Working with the Science Museum, our team shared ideas for a concept design of this application via a blog. The research conducted and ideas generated from the blog allowed our team to generate the majority of its first prototype prior to departure for the London Science Museum.

Before our team began working in the Science Museum, we determined our plan of action for generating the first prototype and testing it in the Science Museum. In order to create the best application possible, our team devised the following set of objectives:

1. Assess the use of digital technologies in museums;
2. Develop prototype and content concepts;
3. Test and revise the prototype; and
4. Provide recommendations to the Science Museum.

This section discusses the details of how we initiated completing each objective in collaboration with staff at the Science Museum.

3.1. Objective 1: Assess the use of digital technologies in museums

In order to make an effective digital resource for teachers in the London Science Museum, we first evaluated the current technologies used in museums that benefit both visitors in general and teachers in particular. We conducted an extensive review of literature. New material was acquired through additional research and interviews both in the preparatory stage and on-site at the London Science Museum.

3.1.1. Interviews and observations at the preparatory stage

In the preliminary stage of our research, we sought advice from several experts who might be able to contribute ideas for our concept designs and supplement the information in our

literature review. Many of these specialists were referred to us by our advisors or were found after doing research on museum and science center websites. We first conducted an interview with Martha Cyr, Head of the K-12 Outreach Program at WPI, addressing how to engage students and how to effectively interact with teachers. We also met with Patrick Moody, who specializes in support services in the IT department at WPI, for technical advice when creating an iPad application to be used in a museum setting. These interviews served as one of the first steps to developing our concept designs outside of archival research and gave us discussion points for future interviews.

Our sponsors at the London Science Museum suggested we visit a local science museum in order to gain insight into the way teachers work in museums and the struggles they face on class trips. We visited the Boston Science Museum because of its close proximity to our campus and the similarities to the London Science Museum in its structure, goals, and exhibition style. Prior to our visit, we spoke with the Boston Museum of Science's School Visit Program Manager, Sharon Horrigan. Ms. Horrigan gave us a brief overview of the digital resources used in the museum as well as activities implemented within the galleries for students. She also set up a meeting for us with Maggie Rabidou, an employee in the Educator Resource Center within the museum.

Upon our visit we observed galleries similar to those we may encounter in London and obtained advice on creating our application. We specifically examined the ways the exhibits were set up in order to engage visitors, the concepts they emphasized about each object, and the way visitors reacted to certain objects.

In addition to interviewing local experts, we also spoke regularly with our sponsors at the London Science Museum through email and Skype calls during the preparatory period. Their valuable experiences working with the Museum gave us clear guidelines to assess current digital technologies in museums. The London Science Museum's website was also useful in giving us insight into what the museum contained in terms of information about certain objects and also what programs and innovative features they offered to visitors.

In order to prepare for the creation of the app, several interviews were conducted via email and telephone. We interviewed various experts in local and nationally renowned science museums, such as Ms. Horrigan, as previously stated, from the Boston Museum of Science and Anne Richardson, Associate Director and Field Trip Explainer, from the Exploratorium. We

also contacted staff at the American Museum of National History and the Liberty Science Center via email.

3.1.2. Observations at the London Science Museum

During the first week on-site, we observed teachers and school groups visiting the Science Museum. Specifically, we investigated the behaviors of teachers and students in museum in a more formal manner compared to our observations of students at the Boston Museum of Science. The purpose was to examine the way in which students interacted with exhibits in the London Science Museum, particularly the *Making the Modern World* gallery, as well as to examine how teachers guide their students through the museum. In order to accomplish these observations in a professional manner, we were first trained in observations by one of our sponsors, Hannah Clipson—audience advocate and researcher at the Science Museum. From this training, we were then able to develop two observation sheets: one for observing teachers and one for observing students (Appendix D: Student Observation Sheet and Appendix E: Teacher Observation Sheet) which we piloted on the floor of the *Making the Modern World* gallery; the process of observing students and teachers took two hours.

3.2. Objective 2: Develop prototype content and concepts

The purpose of the mobile application is to be a user-friendly teacher's guide. Much like the pamphlet currently provided by the Science Museum to teachers, the prototype application that we developed was designed to provide teachers with information such as curriculum relevance for the appropriate age group. However, unlike the pamphlet, the application will be easy to use and navigate and will also provide more useful information, as teachers reported such features lacking in the pamphlet (TW Research, 2007). Not only did our application design address the feedback on and improve upon the pamphlet, but it helped teachers engage their students in learning from objects in the *Making the Modern World* gallery. In order to develop prototype content, there were two stages of development: research/primary development, which took place in the preparatory period before going to London, and secondary development, which took place while on-site.

3.2.1. Prototype development at the preparatory stage

The primary development stage began with extensive research in a variety of topics related to the development and use of learning and teaching tools in museums, as seen in the

literature review. Through this research, we were able to design a basic set of criteria for the application:

- Provide background on specific objects in the *Making the Modern World* gallery;
- Provide entertaining learning activities for teachers to implement with their students; and,
- Include other useful information, such as a map of the gallery with locations of specific objects.

Similarly, the Science Museum staff provided a set of minimum design criteria. Accordingly, the application should include:

- Clear and easily understandable explanations of artifacts and their relevance to age-appropriate curriculum;
- Ideas for activities that a teacher could easily conduct during and after a visit to the Science Museum; and,
- Discussion starters that a teacher could use to engage his/her students in talking about a particular object.

In order to design content for the application that would meet these criteria, our team met three times each week to discuss our progress and ideas for future designs. Similarly, through our weekly Skype calls with our sponsors we received feedback and guidance on our content ideas. Hannah Clipson was able to give us guidelines for the overall process of creating an application for the Science Museum. Jane Dowden from the Learning Resources team provided helpful information on creating a resource geared towards teachers and teacher expectations from such a resource. Anne Prugnon from the New Media team gave technical advice on our prototype concepts.

Fulfilling the request of the London Science Museum, our group created a blog on which we posted our thoughts and ideas for content design in order to facilitate communication of our content ideas. This not only improved both our group and sponsor's ability to keep track of ideas, but it also created a platform where there could be real-time response and exchange of comments between our group and our sponsors in order to synchronize the goals and intentions of this prototype. One of the ideas generated can be seen in the blog screenshot seen in Figure 9. The blog allowed our brainstorming of content ideas to be much more open in that we, the project team, could post any and all ideas, and our sponsors at the Science Museum would be able to

shape our ideas into what they thought would be best for the application and would best follow their criteria.

Figure 9: Concept Blog Post from April 12, 2012

The original idea for the application was prompted by feedback from several teachers surveyed by the Science Museum. The Science Museum found that teachers often feel unsure of ways to engage their students in learning and thus requested that we create a mobile application that would not only help teachers create meaningful learning experiences in the *Making the Modern World* gallery, but would also require no further work for the teacher. Using the criteria shown above, our team developed a preliminary design templates using Prezi as seen in Figure 10 (Reference Appendix B: Concept Design 1 in Prezi, and Appendix C: Concept Design 2 in Prezi, for views of concept designs in Prezi), consisting of four different sections of information and activities: Understand It, Visualize It, Get Involved, and Discuss It—these were further developed into Object Info, KS3 Visual Aids, Activities, and Discussion Q's respectively.

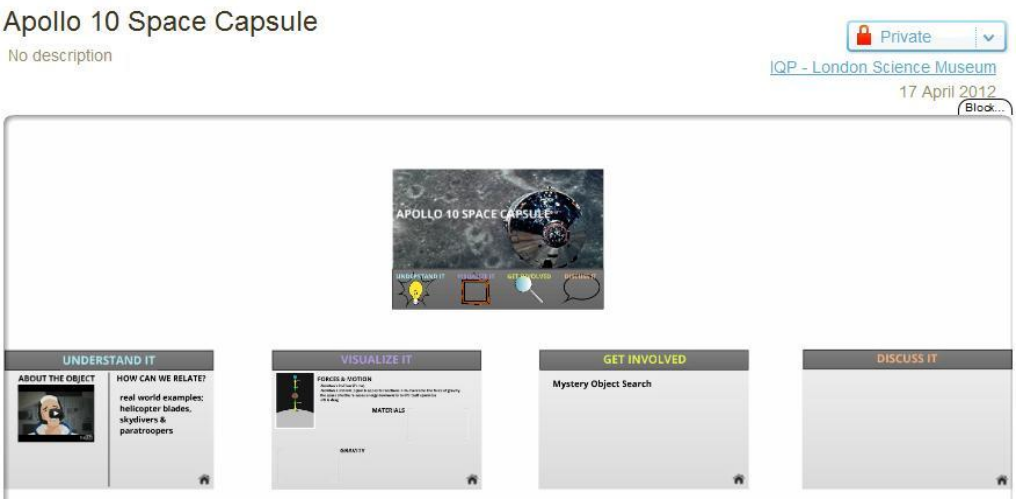

Figure 10: Content Design Template Used with Apollo 10 Space Capsule

The *Making the Modern World* gallery is an object-rich gallery and it would therefore be unfeasible to create an application that applied to every object in the gallery. For this reason, the Science Museum asked us to focus on any four of five specific objects:

- Electric Telegraph
- Stephenson's Rocket
- Ford Model T car
- V2 Rocket
- Apollo 10 Space Capsule

Of these five objects, we chose not to include the Electric Telegraph in order to focus more on the evolvement of technology through more kinetic objects. The template (Figure 10) concept was then transferred to a PowerPoint and tailored to each of the four focus objects in the *Making the Modern World* gallery. This set of preliminary concepts was developed further in the second development phase which occurred while on-site in London.

3.2.2. Prototype development at the London Science Museum

Once on-site at the Science Museum, we presented our preliminary design and content concepts, which had been created during the preparatory period, to staff members of the Science Museum. Based on feedback from our sponsor, Hannah Clipson, as well as from Ann Prugnon, we altered the prototype design. In order to further develop the content of the prototype, we attended a Talk Science teacher-training course run by Jane Dowden.

Because teachers differ from the typical museum visitor, we conducted research specifically geared towards their needs as educators. By doing archival research and speaking to

experts in relevant fields before leaving for London, we assessed what teachers would find to be most helpful in a mobile application. Similarly, attending a teacher-training course allowed us to gather more direct, specific information on teacher wants and needs. The teacher-training course was hosted by Talk Science, a branch of the Science Museum Learning Team. During this all-day course, we joined a group of approximately 40 trainee teachers as they learned ways of engaging their students with science and the Science Museum. The activities in which the teachers participated included exploring the Science Museum's classroom resources, such as a mouse trap-powered paper car, and describing mystery objects. Most importantly, the trainee teachers worked in small groups to develop lesson plans that could be implemented both in the Science Museum and a classroom follow-up. Through this, we were able to observe how teachers engage with their students using discussion, as well as what activities teachers would like to use to engage their students in the Science Museum. We were also able to develop ideas for the content of our first prototype.

3.3. Objective 3: Test and improve the prototype

Our aim for this project was to develop an effective iPad application resource that is geared toward KS3 teachers; therefore, our primary source of feedback was from teachers through on-site accompanied visits. In addition, the entire process involved an interactive process of developing, testing, and reviewing with staff at every stage to ensure that our prototype achieved our sponsors expectations and goals.

3.3.1. Prototype 1 Testing

In order to receive real time feedback on the initial prototype, our group conducted on-site accompanied visits with teachers using the application. The first step in this process was to set aims and objectives for testing (Appendix G: Prototype 1 Testing Aims & Objectives). This allowed us to create a focus for the testing and assure that we could gauge the prototype's success in relation to these goals. Using these objectives, we created a testing questionnaire that included a series of pre-, during-, and post- interview questions, as well as a short preamble regarding the nature of the testing (See Preamble in Appendix H: Prototype 1 Testing Questions and Observation Sheet). The questionnaire, consisting of open-ended qualitative questions, was piloted on the gallery floor with Ms. Clipson as a tester and subsequently revised. Once the interview questionnaire was prepared, testing of the first prototype could begin.

The project team conducted Prototype 1 testing on the floor of the *Making the Modern World* gallery with six KS3 teachers (recruited via email by Hannah Clipson). The accompanied visits were conducted with two team members, one who acted as an interviewer and other as a scribe, testing with one teacher at a time. First, teachers were asked a set of pre-testing questions that inquired into their background with touch screen technologies and with the Science Museum, particularly the *Making the Modern World* gallery. Then, after completing the preliminary questions, teachers were given the iPad with the application already running and allowed to begin testing at their leisure. Because this testing was conducted in the form of accompanied visits, teachers were allowed to explore and interact with the application at their own pace with minimal direction from team members. When questions were posed to team members regarding direction—either in the application or in the gallery—teachers were encouraged to make an educated guess based on the information provided to them by the application.

As teachers explored both the application and the gallery, the accompanying team members made observations. Teachers were asked to think aloud during testing and the designated interviewer asked probing questions to elicit more information in terms of the teachers' choices and reactions as they navigated the application and the gallery (See Appendix H: Prototype 1 Testing Questions and Observation Sheet for a list of probing questions used). The accompanying team member recorded teachers' responses and took note of the order in which teachers used the objects, sections, and methods of navigation. All observations and teacher responses were recorded on the questionnaire developed for Prototype 1 testing.

After teachers had explored both the gallery and the application to their satisfaction, they were escorted to a seat to answer a set of post-testing questions (See Exit Questions in Appendix H: Prototype 1 Testing Questions and Observation Sheet). These questions were designed to elicit teachers' thoughts on engagement, motivation and usability. Engagement was defined as overall impression, likes and dislikes, and understanding of the application. Motivation was defined as desire to use and helpfulness in promoting student learning. Usability was defined as navigability, simplicity, and ease of use.

After testing with an individual teacher was completed, the two accompanying team members typed up their observations of teacher behavior and responses. Teacher responses to pre- and post-testing questions were compiled into a Microsoft Excel document (Appendix I:

Prototype 1 Pre-Question Spreadsheet and Appendix J: Prototype 1 Post-Question Spreadsheet) and observations were compiled into Microsoft Word documents, all of which were then divided into four categories: engagement, motivation, usability, and miscellaneous (responses that were not related to the focus of Prototype 1 testing).

3.3.2. Prototype 2 Testing

After receiving feedback on the usability and functionality of the first prototype, we made necessary changes to the application to prepare it for a second round of prototype testing. Before testing of the second prototype began, we established a list of aims and objectives much like those used during the first testing (Appendix M: Prototype 2 Testing Aims & Objectives). From this, we created a questionnaire which included a short preamble, three pre-questions, observations, and several exit questions (Appendix N: Prototype 2 Testing Questions and Observation Sheet). The format of these questions was kept similar to that used for Prototype 1 to ensure consistency with our testing. The pre-questions related to the teachers' experience with bringing school groups to the Science Museum rather than their familiarity with touch screen interfaces and similar technologies. Because our main goal was not to test the functionality of the app, we kept these pre-questions very concise and focused on teachers' past trips to the museum.

In this testing, the observations section was broken into several sections: Tutorial, Home Page, Gallery Maps, Stephenson's Rocket, Model T Ford, V2 Rocket, Apollo Capsule, and Other. Within these sections were prompts and reminders of certain points to look for, which allowed us to focus on our set objectives and solicit relevant answers from teachers as they used the app. The testing focused on the application's content and usability as well as the engagement of both teachers and students. Due to time conflicts and logistical complications, we were not able to schedule interviews with teachers and their students; rather we followed a similar process to Prototype 1 testing and accompanied one teacher at a time through the gallery as they used the application. Given this, any questions and objectives focused on the engagement of students were hypothetical and teachers were encouraged to imagine using the application as if they were with a school group; the questions we asked focused mainly on how the teacher would theoretically use the app with their students.

As with the first round of prototype testing, teachers were encouraged to use the application independent of our guidance. Following their walk through the gallery, the interviewer asked each teacher several exit questions. These questions were derived from both

our Prototype 1 testing questions and also our objectives for the second testing. This method ensured that our second prototype still met the needs of the first prototype, but also focused on our second set of objectives that were geared more towards content and student (rather than teacher) engagement.

Teachers were notified beforehand of our intention to interview them after their use of the prototype to receive comments, but was clearly stated that this interview will only be conducted with the consent of the teacher in terms of use of data collected. Because teachers have limited time at the Science Museum, the interviews were conducted in the form of face-to-face surveys. As before, interviewers were equipped with the survey, a clipboard and pencil and the questions were asked in the survey order as the scribe filled in the responses.

After the interview, the scribe fully documented the information obtained from the interview. This was done using the same method implemented during Prototype 1 testing. A Microsoft Excel spreadsheet containing the questions and answers to both the pre-questions and the exit questions was created (see Appendix O: Prototype 2 Pre-Question Spreadsheet and Appendix P: Prototype 2 Post-Question Spreadsheet) and was color coded based on the four sections we focused on (engagement, content, usability, and miscellaneous). Microsoft Word documents were also created to record the observations, and were color coded in a similar manner. All findings from interviews will be documented electronically so that findings from an interview can be accessed easily for further analysis if need to be.

3.4. Objective 4: Provide recommendations to the Science Museum

Based on the findings from both prototype tests, we have made recommendations to the London Science Museum in terms of future app development and teacher needs. The recommendations are specifically tailored to the four testing objectives made for prototype testing: usability, engagement, motivation, and content. These recommendations are designed to improve future iterations of the application prototype we created, as well as aid in the development of any similar projects.

4. Findings

This section is a compilation of the analysis of our first three objectives: assess the use of digital technologies in museums, develop prototype content and concepts, and test and improve the prototype. The analysis of the forth objective, provide recommendations to the Science Museum, will be developed in the Conclusion and Recommendations section.

4.1. Objective 1 analysis: assessment of the use of digital technologies in museums

Our first objective involved the development of the application from assessments of research and observations of teachers and students. The findings we compiled from interviews and observations began in the preparatory stage and eventually led to the development of our first prototype.

We interviewed several experts to gain knowledge of the current technology used in the museums. Martha Cyr, Head of the K-12 Outreach Program at WPI, discussed regarding teachers as experts in their field and involving applicable content to students' lives to keep them interested and engaged. Patrick Moody, who specializes in support services in the IT department at WPI, advised us to keep our design simple and easy to use to increase teachers comfort with the application. In addition, we were advised to rely on visuals, avoid being text heavy, and take advantage of the many iPad capabilities.

Additionally, we consulted Anne Richardson, Associate Director and Field Trip Explainer, from the Exploratorium, San Francisco via teleconference. She explained that the Exploratorium was currently using iPads with their explainers, and shared some key advantages and disadvantages to using the iPad as well as several recommendations. The disadvantages of using the iPad are 1) fascination with the device rather than the exhibition itself 2) cost of replacing iPads if lost, broken or stolen, and 3) difficulty navigating the iPad in large groups. Some advantages are 1) real-time updates available, and 2) a possible augmented experience, allowing static objects to become dynamic. Based on the interview, we concluded that we had to ensure the iPad brought something important to the experience and consider how an iPad is different from any other tool. The online resources we received from Ms. Richardson also helped us choose our activities and discussion questions.

Through communication via telephone, Sharon Horrigan, School Visit Program Manager of the Boston Museum of Science, gave us a brief overview of the digital resources used in the

museum as well as activities implemented within the galleries for students. She also arranged a meeting for us with Maggie Rabidou from the Educator Resource Center. Ms. Rabidou informed us that although there are not many guided tours given to teachers in the museum, the worksheets provided to teachers proved useful as they were organized by subject matter and grade level. We adopted this technique when determining how to organize our application's content and we also included a predicted length of time next to each of the activities (so the teachers could choose which one to do based on the amount of time they had in the exhibition), which was suggested to us by Ms. Rabidou. Within the Boston Science Museum we found objects similar to those that we were assigned to (the Stephenson's Rocket and the Apollo Space Capsule), giving us a better idea of how to put static objects into a dynamic element to which students will be able to relate.

Finally, we consulted our sponsors at the London Science Museum through email and Skype calls. From this we were able to communicate to them our ongoing assessment of current digital technologies in museums and how this was affecting our application development. Overall, the findings that were gathered from assessing resources used in museums greatly influenced the way we developed our application concepts and helped us determine what to include in terms of content. Completing our first objective gave us a foundation for the development of our application prototypes.

4.2. Objective 2 analysis: development of prototype content and concepts

The preparatory stage of interviews and observations led to our on-site assessment in the London Science Museum, during which we further evaluated logistics in museum settings. From this foundation, we were able to begin developing our first prototype. The first step in this development process was to gain a better understanding of our target audience (KS3 science teachers) and the objects we were using in the gallery. Following this, we could develop an effective application with relevant, interesting content.

4.2.1. Understanding the audience

In order to better understand our target audience we needed to observe their behavior while in the *Making the Modern World* gallery and also receive direct feedback and advice. To do this our team conducted observations in the *Making the Modern World* gallery and attended a teacher-training course.

'Making the Modern World' Observations

During our first week at the Science Museum, we had several opportunities to observe school groups in the *Making the Modern World* gallery. The school groups we observed were predominately KS3 students, though we observed other age groups to get a general understanding of how teachers and students interacted with each other and with the museum. The purpose of our observations was to understand exactly how teachers were struggling in the gallery and how they were using the KS3 curriculum in the *Making the Modern World* gallery. We also wanted to better understand how students viewed the gallery and to determine how an application could grasp the students' interest for learning. From this, we generated some new ideas for our application that can benefit the teachers and students in this gallery.

The first thing we noticed from our observations was that student groups were led by teachers and chaperones. In these groups, the chaperones did not have the same level of expertise or knowledge as school teachers. Chaperones generally let the students determine the path to take through the gallery. We noticed that the school groups did not seem to understand the chronological layout of the gallery—something that we had discovered earlier in our research—and took random paths which often led to them 'going back through time.' In some groups, the students would stop at an object of choice, and only then would the teacher or chaperone explain what they knew about the object. Usually, the head of the group would simply read the label description next to the object to the students and would then try to generate discussion. This would take about 30 seconds on average. Only in cases where the teacher was knowledgeable about the object, would the group stop for longer periods of time to discuss the object. Younger groups of children tended to only understand the superficial aspects of the gallery—shape, size, color—and the group leaders served the purpose of herders rather than teachers, only making sure the group stayed together from one end of the gallery to other. Some chaperones did not take the time to read or learn about the objects and discuss them with the students; rather, they were more concerned that the children stayed safe and within the group as they explored on their own. This is opposed to some of the older groups, where the group leaders did more to explain the objects while the students still decided the path to take.

While our project goal focuses primarily on teachers, it is important that we also observe the students and how they are responding to the teacher while he/she explains an object. From our observations, we concluded that the engagement of the students is generally paralleled by the

engagement of the teacher. For groups where the teacher took more of a backseat role in the students learning, the students seemed more disorganized and spent less time at each object. For groups where the teacher seemed familiar with the objects and used visual clues to help explain, the students seemed much more attentive and focused, and more time was spent at each object. Students are going to be more engaged in objects and interested in learning if the chaperone or the teacher encourages it; otherwise, the students are left on their own to choose what it is they should do in the gallery. For children who came to the gallery in groups independently, it is apparent that their focus is not based on curriculum learning. Rather, these children go through the gallery choosing objects based on appeal and briefly look at the description labels. They take pictures and meander from object to object without a sense of guidance or direction. These groups usually spend less time than school groups with children around their age. It is important that when teachers direct their school groups through the museum they do so with direction and purpose. Teachers will be able to maximize the students' engagement and learning if they themselves are confident and knowledgeable in the gallery.

The observations we made from watching school groups allowed us to generate ideas for how we believe an application can truly benefit school groups in the areas of learning and efficiency. Most importantly, we determined that this application must give the teacher a sense of direction through the gallery. The teachers should direct the movement of the group so that they are more aware of the objects and can generate discussion questions more easily. If the students themselves are choosing the path, the teacher may come across objects that he/she cannot explain. Though, this movement should not be restricted, as the students seem to learn best when they have the freedom themselves. In this case, it may be best to have activities in the application that allow students to move about the gallery to discover objects for themselves. These activities may also give the teacher more time to 'look ahead' on the iPad application to see what content is to come and what the application can offer. For this application, it is also important that the content about the object is easily accessible so that the teacher can maintain control over the group. Control over the group means that the students themselves are more engaged. We observed that students seemed to be more attentive when the teacher used hand gestures and pointed at specific areas of the objects. In the application, it may be useful to show areas at which teachers can point on the objects to help the students visualize and remain attentive. Our

observations of students and teachers in the *Making the Modern World* gallery greatly influenced the way we designed the application as well as the content we included.

Teacher-training course

To better understand our target audience our team realized we needed to interact with teachers directly and hear their opinions on how they conduct museum visits. During the development of the first prototype, we were able to attend a teacher-training course hosted by the Science Museum. During this workshop we learned about the different methods teachers use to engage their students in both the classroom and in a museum setting. Although these were only trainee teachers, they had useful insight into how they would personally start discussions and engage their students within the museum's galleries.

From the "Mystery Boxes" activity, during which we were all given sealed boxes containing objects we had to identify, we were able to observe how activities could be used to encourage scientific thinking in an entertaining way. A similar activity called "Mystery Objects" involved the teachers guessing the function of unfamiliar objects they were given. Activities like these could be used to encourage evaluation and discussion skills, teamwork, and the ability to make conclusions and provide evidence. These are important skills taught in KS3 classrooms, so it was imperative that we included activities in our application that could aid in the development of these skills. In the "Powerful Questions" discussion, we learned about how teachers attempt to take relevant, fascinating topics they hear their students talking about and relate them to topics being taught in the classroom. Through this activity, we were able to observe teachers make interesting questions that could provoke discussions and really interest their students. This technique was used when we created our discussion questions for the application as we attempted to connect what students *want* to talk about with what they *need* to talk about. Teachers were also given a chance to explore the *Making the Modern World* gallery where we could see their process of planning a visit to the museum and how they would connect it back in the classroom. The methods they used and also some of the activities and powerful questions they created influenced our application's content. This course taught us a great deal about our target audience and the techniques they use to engage their students in various environments, which aided us in the development of our application.

4.2.2. Understanding the objects

Before beginning the development of prototype content, research into the objects' links to the KS3 National Curriculum was necessary. To provide teachers with these connections, we conducted extensive research on the KS3 National Curriculum during our preparatory period in Worcester. This was done through documents and materials provided to us by the Science Museum, such as study guides of the KS3 science curriculum and of the General Certificate Secondary Education (GCSE) science program. Because we chose our objects from the *Making the Modern World* gallery to focus more on the evolvement of technology through kinetic objects, the main topics from the National Curriculum that connected with the objects were forces, materials, and energy transfer. By linking each object to at least two of these three KS3 science topics, teachers have the flexibility to choose which objects or topics they share with students. We formatted the content for each object accordingly, based on which topics were most relevant.

4.2.3. Choosing the interface

After gaining a better understanding of our target audience, we determined the most effective and easy-to-use method to deliver the app's content to teachers. We decided the most effective and simple way to do this was to use Microsoft PowerPoint to create a presentation that resembled a real application. In this presentation of Prototype 1, each slide represented the screen that would be viewed on an iPad (for the complete set of screen images, please refer to Appendix F: Prototype 1 Screen Shots). Navigation through the application was conducted through interactive hyperlinks, which allowed us to control how the content was to be viewed. In order to make testing for Prototype 1 as beneficial as possible, the application was transferred from its computer presentation state to an iPad. However, at this point in time, the only iPad application that can mimic the features of Microsoft PowerPoint with interactive hyperlinks is Keynote—a presentation software developed by Apple. The transition from Microsoft PowerPoint to Keynote on the iPad was done through iTunes, and presented a few problems:

- The program Keynote could not download the PowerPoint, presumably because of its large size (308 slides, 6.83 MB). The PowerPoint had to be truncated by removing slides before it could be transferred to the iPad (156 slides, 5.70 MB);

- Not all the hyperlinks transferred from PowerPoint to Keynote; multiple figures that are "grouped" have the capability to be hyperlinked as a group, while in PowerPoint grouped figures must be hyperlinked individually;
- The conversion changed font settings from the Microsoft based PowerPoint platform Apple based Keynote. Edits had to be made directly in Keynote to account for this change; and,
- The PowerPoint could not be viewed properly on Keynote until all transitions were removed, and the presentation was switched to "Hyperlinks Only" mode.

Once all the issues were addressed, Prototype 1 simulated an actual iPad application without transitions and special iPad features—swiping, pinching, etc.—and also provided all the characteristics required for a thorough testing. Prototype 1 could be easily transferred onto multiple iPads by downloading the presentation as a Keynote file, saving it to a computer, and then uploading it to another iPad via iTunes. This allowed us to test with multiple teachers simultaneously.

4.2.4. Developing content

After gaining a better understanding of our targeted audience, the objects to be included in the application, and the platform to be used, development of the first prototype's content began. The content of Prototype 1 was first developed from comments and suggestions received from the Science Museum staff on our blog and mock-up prototype developed in Prezi. With the help of the Science Museum staff and our previous research, we developed content that would not only engage students, but also help them make the necessary curriculum links.

Before prototype testing began, we designed the basic outline for our application. Our group created a layout of the application to best represent the four objects and their respective information, as well as determined how the objects were to be viewed. We found through our archival research that the *Making the Modern World* gallery has its objects arranged chronologically to represent the change in technology over time. Thus, we arranged the four chosen objects—Stephenson's Rocket, Ford Model T, V2 Rocket and Apollo 10 Space Capsule—in a chronological order in our application, as they appear in the gallery.

For the first prototype, we kept the design of the skeleton simple in order to ensure usability. Based on designs through the blog and visual representations through Prezi, our team designed the first skeleton for the application, seen in Figure 11.

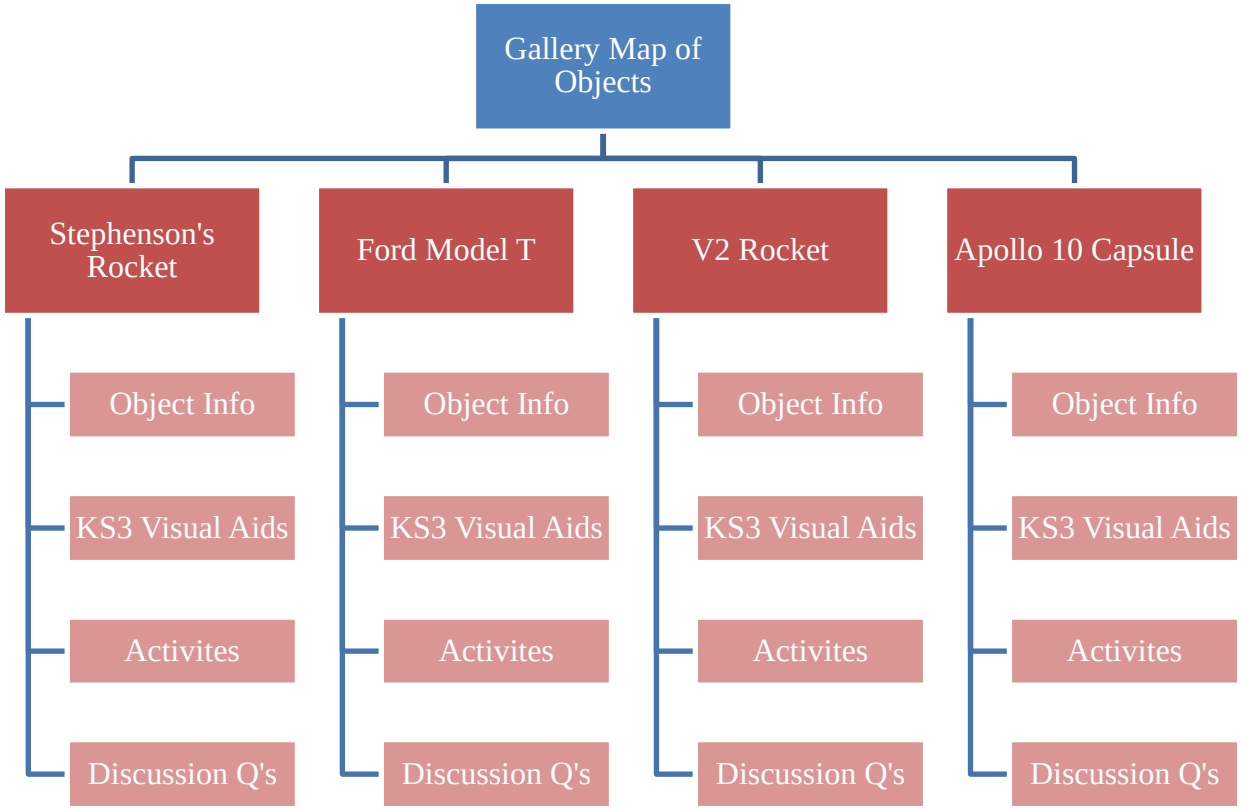

Figure 11: First application skeleton based on preliminary research

The objects were displayed in a map of the gallery (represented in blue in Figure 11), and teachers were able to choose the objects by touching on their respective pictures on the iPad. From this basic skeleton, we had to decide how to go from each object (represented in red) to the content itself. In preparing for this project, we were given a set of requirements provided by the Science Museum to guide us in developing our application's content, which became very useful in this stage. They stated that the digital interpretation was to include:

- An exploration of one (or more) of each of the objects scientific principals—which is directly linked to the National Curriculum;
- Quick, accessible information about the object and its scientific principle through an innovative digital interpretation/communication approach—this could be in the form of film, text, diagrams, AV, animation etc.;
- Clues for the teacher on how to elicit responses from their students about the object;
- Ideas for discussions or investigations the teacher can run based on the object and linked to the KS3 Science National Curriculum; and,
- Activities the teacher can lead based on the object.

Based on this set of guidelines from the Science Museum, we devised four distinct sections for each object to maximize engagement and to ensure that teachers would be able to get the most of this application—Object Information, KS3 Visual Aids, Activities, and Discussion Questions (seen in Figure 11). From these tabs on each object page, teachers were able to access the objects' content. We arranged the sections in this order because it is a logical progression of how teachers might present information about objects to their students.

Object Information

The first section of content is the Object Information, contained interesting facts about each object. The facts portrayed are short and specific and are geared towards the specific interest of KS3 students. The content of this section was developed through background research about the objects compared with the information already available through the description panel next to each object. The aim of this section is to provide appealing facts and figures about the object so that teachers can engage their students from the start, and so that they can establish a platform for learning that can be developed with more of the application's content.

KS3 Visual Aids

The KS3 Visual Aids section consists of information on how scientific principles of KS3 curriculum connect with the objects themselves. It shows through images and diagrams how KS3 science topics relate to each object. The visual aid pages, through the use of information, figures, and diagrams, explain how the museum objects implements the basic science principals that are taught in the classroom (i.e., forces, energy transfer, and materials).

Activities

The third section, Activities, contains student activities to be used specifically on the museum floor. The goal of these activities is to create a more engaging, interactive and meaningful experience for these students during their museum visit. The initial activity concepts were created based on research and communication with various museums across the United States and education pages on various museum websites. These concepts were then refined using the museum activity ideas presented by teachers during the Talk Science teacher-training course. In the application, each activity is color coded to match a one of the three specific KS3 topics utilized in this digital resource. Estimated duration of each activity is provided next to each activity title to assist teachers in managing their time while in the gallery. While the application

is limited to only four objects of the hundreds on display, the activities allow the students to make use of the entire gallery.

Discussion Questions

The Discussion Questions section consists of a mix of questions that teachers can discuss with their students. Like the activities, these questions were developed through research and communication with various museums across the United States and education pages on various museum websites. The questions were strengthened to be more open-ended and to play to the interests of the students based on a session during the Talk Science teacher-training. Each question is shown entirely and acts like a hyperlink that is linked to a slide where the answer to the question is provided. In addition, tips and insights on how the teacher could promote discussion with these discussion questions within their student groups are provided on this slide. The aim of these discussion questions is to enhance educational value by either provoking already learned knowledge from the National Curriculum or encouraging thinking in a scientific and analytical way.

After presenting this initial design to the New Media team at the Science Museum, we modified the design to incorporate two distinct paths on the home page for teacher's to choose from: an *Objects* path, which includes all four objects and all of their KS3 relevant topics, and a *KS3 Topics* path, which groups the objects based on specific KS3 topics—force, energy and materials. This modification allowed teachers to have more options (represented in green in Figure 12) when viewing the gallery. This design was adopted for testing for Prototype 1. The skeleton can be seen in Figure 12.

Figure 12: Prototype 1 skeleton based on suggestions from the New Media team

As can be seen when comparing Figure 11 and Figure 12, the skeleton for Prototype 1 encompasses much more content and expands the function of the digital resource. As can also be seen in this skeleton, our team added a tutorial page to portray the features of the digital resource to teachers who might not be familiar with this type of technology. Once the skeleton for Prototype 1 was established, our team added the content sections to the individual objects and prepared it for testing.

4.3. Objective 3 analysis: Tests and improvements of the prototype

We conducted both Prototype 1 testing and Prototype 2 testing on the floor of the *Making the Modern World* gallery. Through accompanied visits, we walked with teachers while they used the application and explored each of the four focus objects.

4.3.1. Prototype 1 Testing findings

The goal of the first prototype testing was to test the usability and functionality of an iPad resource with teachers. The testing for Prototype 1 was accomplished through on-site

accompanied visits with six teachers using the application in order to receive real time feedback on initial prototypes. From testing directly on the museum floor, we could identify the barriers that hindered these aims of Prototype 1 and address them in later prototype developments.

After Prototype 1 testing was complete, we compiled observations and teacher responses to pre- and post-testing questions (See Appendix I: Prototype 1 Pre-Question Spreadsheet and Appendix J: Prototype 1 Post-Question Spreadsheet for complete screenshots of our data spreadsheet). We then coded these data into four categories based on the objectives of Prototype 1 testing: engagement, motivation, usability, and miscellaneous (responses that were not related to the focus of Prototype 1 testing). The key findings below are organized according to these same categories.

Engagement

The overall reactions to the prototype application were very positive and the teachers were clearly engaged while using it. All of the teachers claimed to have learned something new from the application, whether it was about the objects or new ways to engage students in the museum. Although 3 out of 6 teachers believed erroneously that this application would be used by students instead of being used solely as a teacher's resource, all six teachers understood that this application would be used to engage students in the objects seen in the museum by interesting facts, visuals, activities, and discussions. All six teachers believed that this tool would be a very helpful museum resource. The four different sections of the application (object information, visual aids, activities, and discussion questions) were well received, but teachers found the discussion questions and activities most appealing because they are interactive, relevant, and interesting. The application's flexible and relevant content convinced teachers that while the application is better suited for a museum setting, it could also be used in the classroom. All of the teachers expressed interest in finding a way to connect the application to lessons that might be conducted in the classroom both before and after the museum visit.

Motivation

The majority of teachers (5/6) would enjoy using the application in future school visits to the Science Museum and believed that it would help engage students in learning through interaction with the application and the objects. However, there are two primary barriers to teachers' motivation to use the application: inability to prepare for use and the usability of the visual aids. Half of the teachers (3/6) felt that they would find it difficult to use the application

fully and confidently without being able to prepare after seeing the application's information in advance. Four of the six teachers indicated that they would really like to share the visual aids (e.g., depicting forces at play in the V2 Rocket), but the small size of the iPad screen inhibits sharing this information easily with a group of students. Thus, the usability of the visual aids is limited.

Usability

The teachers unanimously agreed that the design of the application was simple and it was easy to follow once they became acclimated to it. Every teacher quickly learned what each section would contain due to the consistent material within each section. Teachers initially struggled with navigating and understanding the functions of certain features such as the hyperlinks for the zoomed pictures and diagrams and where hyperlinks were present. This is because the labels 'Touch to Zoom In' were small and not easily visible, and also because only a selected portion of the pictures and diagrams were hyperlinked. This confusion could also stem from teachers skimming or completely skipping the tutorial page. The tutorial was a single page preface to the application itself, and thus, teachers skipped the tutorial in order to view the content, although all six teachers reported finding it helpful to have.

After using the application for one or two objects, it was observed that all the teachers could navigate through the application and use it effectively because they found it simple and easy to use. However, there was some ambiguity with the map. Although the plane was present as a reference point, this was not clear to every teacher. In addition, the angle of the plane's wings on the map in relation to the gallery was incorrect. Thus, while 5 out of 6 teachers found the map helpful, teachers who were not familiar with the *Making the Modern World* gallery initially struggled to confidently navigate the gallery.

Content

All six teachers believed the application would aid them in delivering relevant information to their students while on museum visits and connecting the objects to relevant subjects. All of the teachers perceived the content in the application was not only engaging, but also directly linked to the Key Stage 3 National Curriculum.

Overall, the majority of teachers enjoyed each section: 5 out of 6 teachers believed their students would be engaged in the object information, 4 out of 6 believed their students would be engaged in the visual aids, 5 out of 6 believed their students would be engaged in the activities,

and 4 out of 6 believed their students would be engaged in the discussion questions. There was no singular section which teachers found unanimously interesting and engaging nor was there a teacher that was consistently negative towards each section of the app. This was because of both usability barriers, in terms of difficulty sharing visual aids with large groups, and the content itself, in terms of wanting more and different information about the objects.

4.3.2. Prototype 2 Development

After receiving feedback on the usability and functionality of the first prototype, we made the necessary changes to the application such that it was equipped for the second round of prototype testing, which focused on the prototype's content. One of the major changes to the format of the prototype was through an update of the skeleton design. Because two teachers reported being confused by the 'Objects' path and the majority (4/6) of teachers preferred the 'Topics' path, we removed the 'Objects' path and instead created a fourth option labeled 'All' under the 'Topics' path that includes the information, visual aids, activities, and discussion questions for all KS3 topics for each object. This allowed the design to be much more straightforward and without sacrificing any of the depth of the application. The new skeleton can be seen in Figure 13.

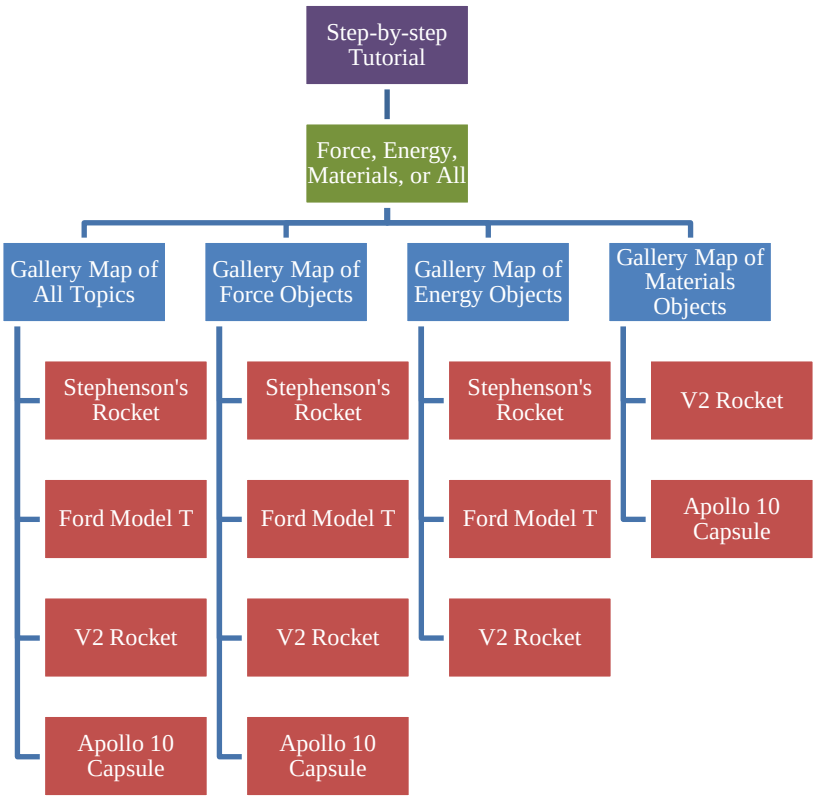

Figure 13: Prototype 2 skeleton based on findings from Prototype 1 testing

Other changes to the design of Prototype 1 included removing the tab feature, as it went unnoticed by the majority of teachers (4/6) and confused the two teachers who touched it accidentally. Teachers navigated just as easily without it. The tab feature mimicked the pull down tabs on iPads and was intended to be a means to move between objects. Though it was removed for Prototype 2 testing, our team noted that if this app were to be used with more objects, a tab feature may be helpful where a map can become overcrowded. Figure 14 shows the use of the tab feature.

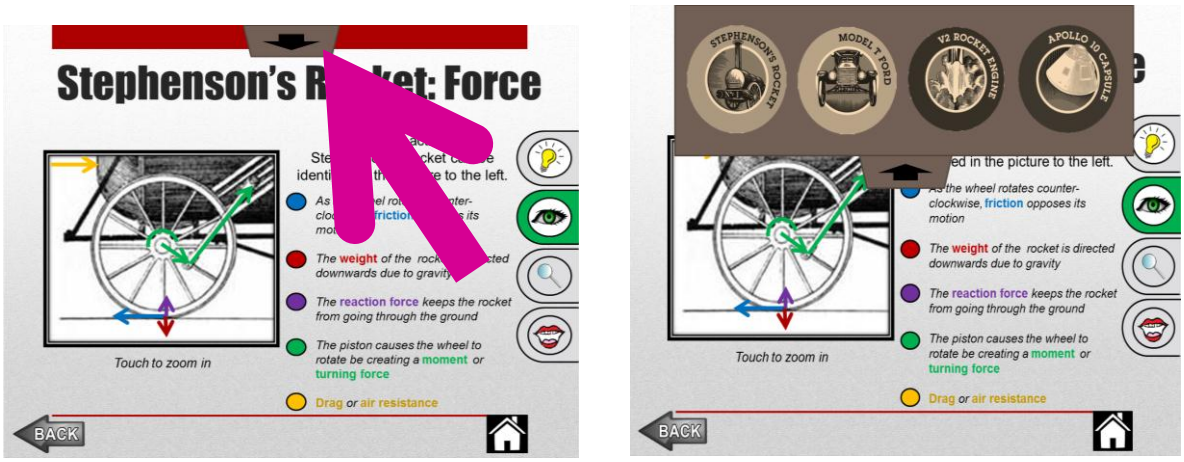

Figure 14: Demonstration of the implementation of the Tab in Prototype 1

Changes also included removing the underlining of the discussion questions and fixing various grammatical and spelling errors. In addition, we altered the gallery map (Figure 15) to avoid confusion in teacher navigation. To do this, we highlighted the entrance to the gallery on the map and corrected the angle of the plane's wings such that it better matched they physical gallery. To ensure that the plane could more easily be used as a reference point, it was labeled as such on the map.

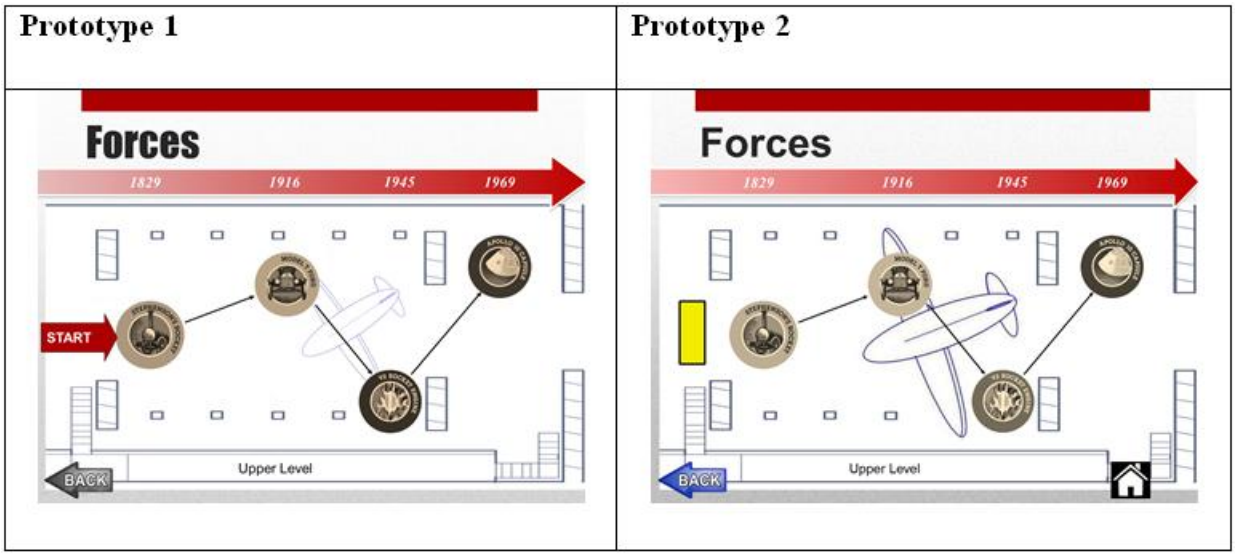

Figure 15: "Force" Gallery Map of Prototype 1 and Prototype 2

In order to address the difficulty in sharing the visual aids with students, more pictures were hyperlinked to a zoom feature, which was labeled with a magnifying glass in the corner of the image. This allowed a greater number of images to be large enough to share with student groups and clarified which images could be enlarged.

To facilitate teachers' use of the discussion questions, we ranked the questions for each object by level of difficulty, from easiest to most challenging, using an arrow to indicate the direction of increasing difficulty.

In order to encourage teachers to fully read and understand the tutorial, we made it a step-by-step process that must be completed in order to view the application's content (Appendix K: Prototype Tutorial Development). Teachers are not able to exit the tutorial until they reach the final page. This will not only encourage absorption of information, but also ensure that teachers are not overwhelmed by the information given on any individual page of the tutorial. All of these necessary changes made to the first prototype prepared it for the second round of testing with Prototype 2.

4.3.3. Prototype 2 Testing findings

The goal of the second round of prototype testing was to test the usefulness and curriculum relevance of the app's content as well as to continue testing the app's usability. We also hypothetically tested student engagement based on teachers' opinions. Like testing for Prototype 1, Prototype 2 testing was accomplished through on-site accompanied visits with seven teachers using the application. From testing directly on the museum floor, we could

identify any barriers that hindered engagement and determine how to move forward from the prototype.

After Prototype 2 testing was completed, we compiled observations and teacher responses to pre- and post-testing questions (see Appendix O: Prototype 2 Pre-Question Spreadsheet and Appendix P: Prototype 2 Post-Question Spreadsheet). We then coded this data into three categories based on the objectives of Prototype 2 testing: content, engagement, and usability. The key findings below are organized according to these categories.

Content

As a whole, teachers reacted positively towards the content of our app. Teachers agreed that the app's content was helpful and relevant for KS3 students. For each topic, the majority of teachers (at least 6 out of 7 per topic) found the content relevant to the KS3 National Curriculum. Teachers enjoyed the four object subgroups (Object Information, Visual Aids, etc.), and there was no singular section that was preferred. Teachers responded very positively to the new arrangement of questions by difficulty level. Every teacher believed the ranking would be useful in helping them select the appropriate difficulty level for their students. However, because some of the topics and content is quite challenging, teachers felt that more activities need to be developed for younger and lower ability level students, as teachers often come to the Science Museum with mixed ability groups. With this in mind, teachers enjoyed the flexibility and control of the content in that they could choose which activities and discussions to use depending on the needs and abilities of their students.

Teachers also expressed an interest and need for a greater range of activities to be available in the app. While teachers loved having a set of example activities and questions given to them, many teachers also expressed interest in putting their own creative or personal touch to these examples to better cater their own students.

Engagement

All teachers reported that using the app would help them engage students in learning from the *Making the Modern World* gallery. However, 3 out of 7 teachers expressed a desire to supplement this engagement with additional materials, such as worksheet companions to the application. Having a tangible outcome for students not only gives a physical reminder of the lesson, but also helps focus the students towards their tasks while in the Science Museum, where it is sometimes difficult for teachers to retain students' attention for long periods of time.

Despite their desire for supplementary materials, teachers did feel that students would be engaged in the content provided by the app. Similarly, the majority of teachers (5 out of 7) agreed that the app's content caters to a range of KS3 students (i.e., according to differing ages and abilities). However, two teachers felt that the content was too challenging for younger or less advanced ability students because the content, though intended to engage KS3 students as a whole, often requires higher level thinking skills. This, unfortunately, leads to lower level students losing interest in the lessons being taught within the gallery and becoming disengaged from the experience.

Usability

All teachers reported that they would find the app helpful on a museum trip. In this, the majority of teachers (5 out of 7) felt that the app would especially help in terms of logistics (i.e., organization, navigation, and timing). This is because the app provides teachers with easy access to information and navigation, allowing them to focus on organizing their students. Similarly, the time estimates assigned to each activity can help teachers choose activities based on the group's schedule so as not to rush the students' learning experiences.

After changing the tutorial from the original, single-paged to tutorial, to a multi-step, interactive process, we found that the step-by-step method is effective in encouraging teachers to read the information more fully. The majority of teachers (6 out of 7) read all the information and felt that the tutorial was helpful. This is because, in contrast to the tutorial in Prototype 1, the information on each page is concise. In addition, the interactivity of the tutorial is helpful because teachers are explicitly instructed to test the buttons and links, which aids their understanding of how to fully access the app's content and each of its features.

Despite the fact that teachers found the tutorial pages helpful, the majority of teachers (5 out of 7) did not fully understand how to navigate the app. Teachers were especially confused in using the buttons at the bottom of the screens (e.g., the "Back" button). This is because the path to return to the Home Page is complicated – teachers have to return to the object home page before returning to the Home Page – and the back button only takes users back to the previous page viewed, rather than regressing in a linear fashion. However, after some initial acclimation to the app, all teachers felt that the app flowed well and was easy to use. This is because, although the navigation path is somewhat complicated, it is consistent.

Although this app was designed to stand alone and negate the need for teacher preparation, all teachers felt that it would be important to have access to the app's content before using it with students. The majority of teachers (6 out of 7) would want the app prior to arriving at the Science Museum rather than just before using it on the museum floor.

With our final round of testing completed, we were able to compile our findings, discover gaps in our prototype, and formulate recommendations for the museum. With these recommendations we hope the Science Museum can further develop our app and continue creating new, innovative learning tools in the future.

5. Conclusions & Recommendations

Using the analyzed data collected from on-gallery testing of Prototype 1 and Prototype 2, we were able to determine patterns in teacher responses. From these key findings we concluded that the app was an easy to use, engaging tool that teachers are motivated to use. Using this information, we are able to provide recommendations to the Science Museum based on each testing objective: engagement, motivation, usability, and content.

5.1. Engagement

1. **The app is a useful tool that teachers enjoy using.** Teachers are not only engaged in using the app themselves, but can imagine using to engage students in learning from the *Making the Modern World* gallery.
2. **Teachers can be confused about the app's purpose.** Although teachers understood that the app was meant to be used to engage students in learning, some teachers believed that it is intended for students as well as teachers.

   Recommendation: To ensure that teachers fully understand the purpose of the app as a teacher tool, we recommend that this fact be explained further before teachers begin using the iPad by stating this in the information given to them pre-visit, or through the tutorial/introduction page within the app.
3. **The app, though an effective tool, can be overwhelming.** Teachers enjoyed the app's design and content, but felt that they would like to prepare for Science Museum visits by seeing and exploring the app ahead of time.

   Recommendation: To help teachers feel more comfortable in delivering the app's content and engaging their students in learning from the museum, we recommend that the Science Museum provides access to either the entire application or a tutorial and introduction to the app pre-visit so that teachers can:

   a. Prepare their lessons in advance in order to develop pre-visit work in the classroom; and,
   b. Build an understanding of the app's capabilities and content.

   This can be done by email or via the Science Museum website, as expressed through interest by teachers.

   Recommendation: When teachers are given pre-visit information, we recommend that it include a brief summary of what each section on the object page will contain. If read, this

will help teachers quickly understand what new information they will gain from each section before using the application.

4. **Teachers want to continue their lessons from the Science Museum into the classroom.** Teachers want students to have the experience of interacting and making curriculum links with the gallery, but also want to extend to the classroom the lessons learned in the museum.

   Recommendation: We recommend that additional information or activities are included on the Science Museum website for post-visit sessions in the classroom. Because the students will have more space and supplies in the classroom, we recommend that such activities be more hands-on than those available in the application.

5. **Although the app is better suited for use on-gallery, it can be used in the classroom.** Teachers felt that some of the activities, discussions, and visual aids available in app can be done in the classroom as well as the museum or are more suitable for a classroom setting.

   Recommendation: It is important that each section (i.e., activities and discussion questions) needs takes advantage of the museum setting. To accomplish this, we recommend that the content be further developed to include the ability to go to other sections of *Making the Modern World* or other galleries as well as focusing on the physical objects themselves, which cannot be experienced in the classroom. This will help students make the link between the Science Museum as a whole and the KS3 curriculum.

5.2. Motivation

1. **The app is helpful tool and teachers are motivated to use it.** Teachers feel that the app would be effective in engaging students in learning through the ability to impart information, share visual aids, lead activities and promote discussions.
2. **There is a clear link between the app and the KS3 science curriculum.** Teachers felt that the app catered to a of range KS3 students' ages and abilities. They also noted that the content appropriately linked the objects to the National Curriculum.
3. **Teachers want supplementary materials for students to use while in the Science Museum to help further engage them in learning.** Although teachers feel that the content available in the app would be engaging for students, there was a desire for a

physical supplement to give to students to help them focus on their tasks and be more involved.

Recommendation: There was broad support for supplemental material, such as worksheets, to be available to teachers. Therefore we concluded that the Science Museum should make such materials available via email or the Science Museum website in order to aid teachers in engaging students in the app's content and the *Making the Modern World* gallery.

5.3. Usability

1. **The app is simply designed and easy to use.** Once teachers were acclimated to the app, they found it easy to use and navigate and knew where each button would take them.
2. **Some teachers could not orientate themselves using the gallery map, and some found the navigation buttons (back button & home button) confusing to use at first.** Although few teachers could not really orientate themselves with the map and got confused with the navigation buttons, teachers ended up commenting that the app was simply and easy to use because the app's navigation path is consistent throughout and teachers only needed time to get used to it.

   Recommendation: It is important that various design aspects (map, tutorial, and navigation buttons) are improved in order to increase the ease of navigation throughout the map. Various buttons should function as how people would intuitively expect them to function. Consider using other applications, such as the James May App, to better adjust the map and navigation feautres.
3. **Teachers would find the app easier to use if they could see it before using it on-gallery.** Although teachers found the tutorial helpful, few read it in full; teachers prefer to familiarize themselves with the app by exploring it rather than reading the tutorial.

   Recommendation: In order to guarantee usability on the museum floor, teachers need about 5-10 minutes using the app before they enter the gallery. Since teachers are pushed for time on their visits, we recommend that teachers have access to the app before using it with a school group. This can be done in the following ways:

   a. If teachers have an iPad, they should be prompted to download the app and understand its capabilities before coming to the museum.

b. If teachers do not have an iPad, the Science Museum should provide them with a tutorial of how to use the app with a layout of the application content in a document format (Microsoft Word, PDF, Video, etc.) which can be accessible via email or the Science Museum website.

5.4. Content

1. **Ensure that the application is kept up to date with the National Curriculum.** Since the KS3 National Curriculum constantly goes through many changes, both minor and major, ensure that the application is abreast to ensure that teachers can use this type of application effectively.
2. **The object information pages are interesting and useful.** Teachers felt that students would be engaged in the facts displayed on the information pages. However, some teachers felt that access to more and different information would be desirable if students wanted to learn more.

   Recommendation: In order to provide more information without crowded the object information pages, we recommend that the Science Museum include links to websites that provide more information that teachers can access while on-gallery in the classroom.
3. **The activities were engaging and related to the KS3 curriculum.** Teachers believed that students would enjoy and learn from the activities, but felt that some activities were too advanced for younger or less advanced students.

   Recommendation: In order to ensure that students of any KS3 age or ability level can be engaged in the activities available in the app, we recommend that a wider range of activities be developed and ranked based on difficulty as well as KS3 topic (forces, materials, etc.) such that teachers can choose activities to do based on both topic and ability level of the students.

   Recommendation: Development of the content material in the app should be aided by KS3 teachers to ensure the following is provided: relevance to KS3 curriculum, a range of interesting activities and questions for students of varying abilities, and flexibility within the app's content.

   The discussion questions are useful and creative. Teachers felt that the discussion questions were helpful in eliciting deeper thought about a topic or object.

5.5. Recommendations for Future Works

This project is first of its kind at the Science Museum in terms of a digital resource for teachers. We have begun to explore a portion of the advantages that this type of application could provide, though there are many facets of this application that are still undeveloped in terms of evaluation and research. To further develop this resource, we have developed the following top-tips for the Science Museum:

1. **The Science Museum should test further prototypes of this application and test them with school groups.** Our testing was limited to only KS3 teachers. Though we tested the engagement of students and the app's usability with students hypothetically, it is imperative that the device be tested with actual school groups to get a true understanding of its engagement and usability.
2. **KS3 teachers must be consulted in areas of application content and pre- and post-materials.** Since the application is catered towards teachers, it would appropriate that teachers have input into what content would be most appropriate for their students. Consultation must occur with multiple teachers to account for the differences in terms of KS3 Science National Curriculum levels, student abilities and student behavior.
3. **We recommend adding more objects, galleries, curriculum topics and curriculum years.** This application has the potential to be expanded to make it a true museum resource and not have it be limited to the *Making the Modern World* gallery. Teachers expressed interest in this sort of expansion to include more objects and galleries to further engage their students. This expansion would also give teachers more freedom in using this type resource in the Science Museum. With the expansion of objects, new KS3 topics must also be explored. Consider also expanding the app to incorporate other curriculum levels other than only KS3. This will open the application to a larger portion of the school group audience of 380,000.
4. **Consider making the application a multilingual device.** We observed that English-speaking school groups are not the only school groups that tour the *Making the Modern World* gallery. In order to reach out to foreign school groups and not have this app be limited in its intentions, we recommend creating a feature in this application that would allow for it to be viewed in multiple languages.

5. **Share lessons learned with other museums.** Since this type of research is new in terms of developing digital resources for teachers, it may be beneficial for other museums that have school groups as a major demographic—such as the Victoria and Albert Museum or the Natural History Museum, London—to use this research to generate their own forms of digital resources for teachers.
6. **Keep up-to-date with new developments at other museums in London and with technologies.** In terms of development of technology, museums develop new and innovative ways to interpret that technology just as the Science Museum has done with the teacher application. The Science Museum must be aware of the works of other museums in terms of their research into evolving technologies in order to best engage its audience and attract visitors. The Science Museum must also be cognizant of new changes in technology and implement them in the same it has done with the teacher application.
7. **Explore adapting the app to create a student version, and creating similar apps for public use.** Through expressed interest of teachers, it may be beneficial to create an adjunct student version of this application. Many students carry smart devices so it would be easy for them to download the app and follow along with the teacher. Having a student version of the app would also allow students to explore and learn independent of a teacher. Explore also creating a similar application for public use and evaluate how it might cater towards this type of audience in terms of engagement.
8. **Advertisement.** Ensure that the final application is well advertised so that teachers are aware of the application, its function, and how it can be accessed. Consider having the application pre-downloaded onto an iPad for teachers to use when they come into the Science Museum, or consider having the application available to download for teachers who already possess iPads.
9. **In future iPad projects ensure that testing occurs with an iPad interface that suits the aims and objectives of the projects.** For our testing, we were limited to Keynote as our interface choice since it is currently the only presentation software that allows transitions through hyperlinks. It is limited however because it is specific to Apple products. As more presentation softwares are developed, it is imperative that the Science Museum choose one that is most appropriate for the needs of the testing. For example:

Should the app feature iPad gestures (swipe, pinch, double tap, etc.)? Does this application need transition features? What are the limitations of the interface? Do I need to test on the iPad? All of these factors must be considered in choosing the appropriate interface for testing.

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Appendix A: Sponsor Description

The Science Museum, in South Kensington, London, is a public, non-profit institution dedicated to furthering scientific knowledge and exploration. According to the museum's webpage, "Museum history," the birth of the museum originated from the Great Exhibition of 1851 in Hyde Park (n.d.). The exhibition proved to be very popular and its monetary success was used to create various permanent educational facilities. The first of these "museums" was the South Kensington Museum, which opened in 1857, and was primarily a museum of industrial and decorative arts with a few miscellaneous science collections (Museum of Science, "Museum history," n.d.). Throughout the 1860's, the science collections were gradually transferred from the museum into other buildings across the road, which allowed the collections to expand. In 1883, the Science Library was established to serve the research needs of the museum staff (and it continues to serve this need today). At this point, it was decided by the scientific community that the science collections and library of the South Kensington Museum were significant enough to demand both an independent building and an independent institution (Museum of Science, "Museum history," n.d.). From this, the Science Museum was born.

Figure 1: The East Block of the London Science museum during construction in 1919 (Science Museum, "Construction," n.d.)

Although the London Science Museum became independent of the South Kensington Museum in 1908, the building itself was not completed until 1928 (Figure 1).

The first exhibitions in the new Science Museum were geared towards visitors with a background in science; the designs themselves were simple, but the object labels were long and complex. In order to tailor the museum to the needs of a visitor without a background in science, Director Henry Lyons created a "Children's Gallery," which opened in 1931 (Museum of Science, "Galleries and Exhibitions," n.d.). Using pleasing displays with interactive models

(Figure 2), Lyons' goal was to stimulate children's interest in science. Under Lyons' direction, the museum also displayed modern developments and environmental issues in science.

Figure 2: The "Pulleys" Interactive Exhibit, the Children's Gallery, 1951 (Science Museum, "Pulleys," 1951)

To determine what types of galleries, exhibitions or programs are to be run, the museum must first understand who its audiences are, their needs and motivations. Rigorous audience research and advocacy help decide all major projects and underpins future strategic developments in the museum. Evaluations succeeding the premier of any gallery, exhibition or program ensure that the museum continues to improve and achieve excellence (National Museum of Science & Industry [NMSI], 2011). The galleries and other functions run by the museum consist of two primary types: object-rich galleries-and hands-on galleries, as well as several others which are combinations of the two. Object-rich galleries, such as *Making the Modern World* and *The Secret Life of the Home,* feature many historical artifacts with information about their historical and social significance. According to BBC News, the Science Museum displays about 15,000 objects at a time to suit the needs of its current galleries and exhibits. This total figure of 15,000 objects is a mere 7% of the total objects the museum has acquired since the Great Exhibition, as most of the objects are stored at the Blythe House in West Kensington (Amos, 2004). The gallery *Making the Modern World* features only about 150 or 1% of the total objects on display. The other type of galleries offered at the museum are hands-on galleries, such as the *Launch Pad* (Figure 3) and *Fly Zone Flight Simulators*, which feature interactive displays and activities to engage the visitors (Museum of Science, "Galleries and Exhibitions," n.d.). The Science Museum offers a large variety of exhibits which are appropriate

for children of many different ages. Also, it not only offers guidance based on age group or special needs, but also provides materials to help teachers better educate and engage student groups in the museum.

Figure 3: Kids explore the Big Machine—an object in the *Launch Pad* Gallery (Science Museum, "Big," n.d.)

Like any museum, the Science Museum's purpose is to educate and inspire its visitors. As stated by the NMSI (2011) in its most recent annual report and accounts, "we (the museum and its personnel) seek to engage audiences so they have a life-enhancing experience. We aim to give them a sense of awe and wonder, a learning experience that is out of the ordinary and that they refer back to, an insight that helps them make sense of their world and enhances their lives." The Science Museum in particular does so by "combining its unparalleled collection of historical objects with cutting-edge technology and contemporary science news and debate" (Museum of Science, "About us," n.d.). More importantly in the London community, the museum serves as an informal learning institution to aid the formal education system of London (Museum of Science, "About the museum," n.d.). By serving the teachers in developing a digital resource to aid their teaching in the London Science Museum, our project will match the mission of the museum—to help people understand the science that helps shape the lives of others.

The engagement of the teachers' curriculum plays a large role in the attendance of school groups to the Science Museum. Unlike most other audiences that the museum attracts, teachers visit the museum more for educational rather than recreational reasons. A teacher's visit to the museum with a school group tends to be an annex to classroom learning; the museum provides educational experiences that cannot be provided in the classroom. According to the museum's webpage, "Facts and Figures" (n.d.), the Science Museum welcomes over 2.7 million visitors on

average each year, 13% of which come as a booked school group (Figure 4) (National Museum of Science and Industry [NMSI], 2011).

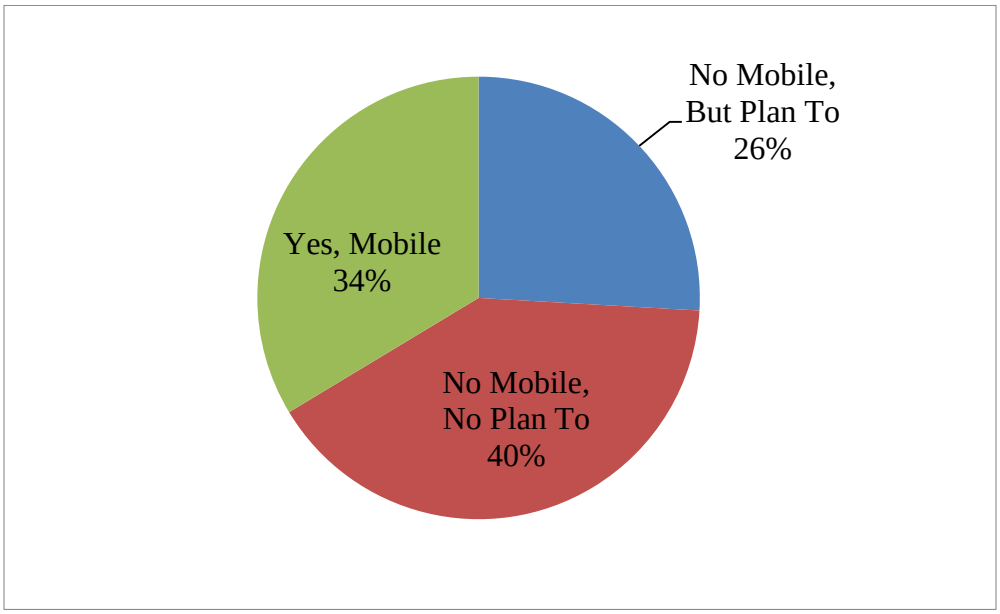


Figure 4: Group demographics of science museum visitors (National Museum of Science and Industry [NMSI], 2011).

From the accounts of the NMSI from 2010-2011, the number of visits from children under the age of 16 reached over one million with 1,074,128 visits; 700,000 people participated in Science Museum learning activities; 11,077,629 people visited the museum's website; and 367,470 visitors came to the Science Museum in booked education groups, as it remains as one of the top science museum destinations in the world (Figure 5) (Walhimer, 2012).

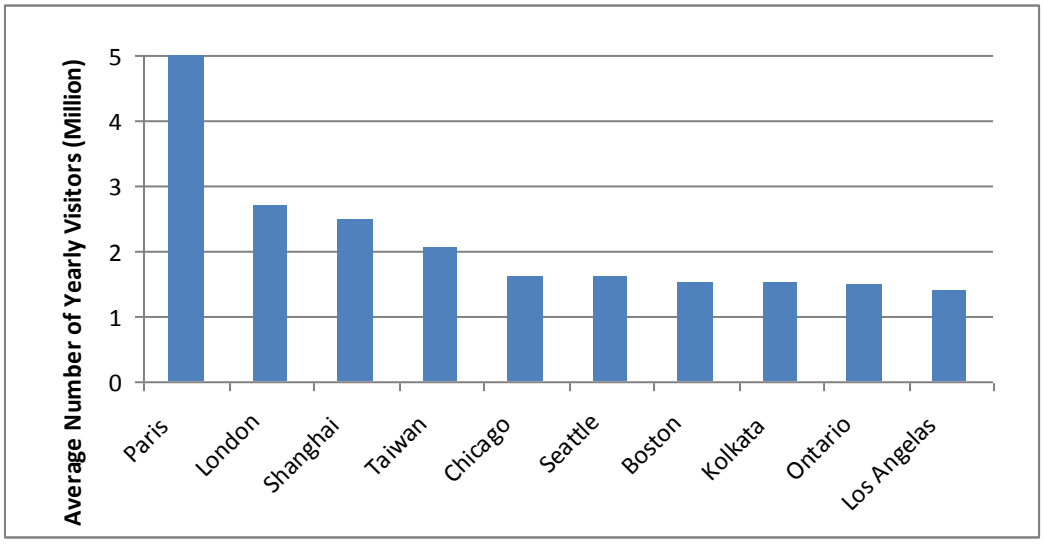
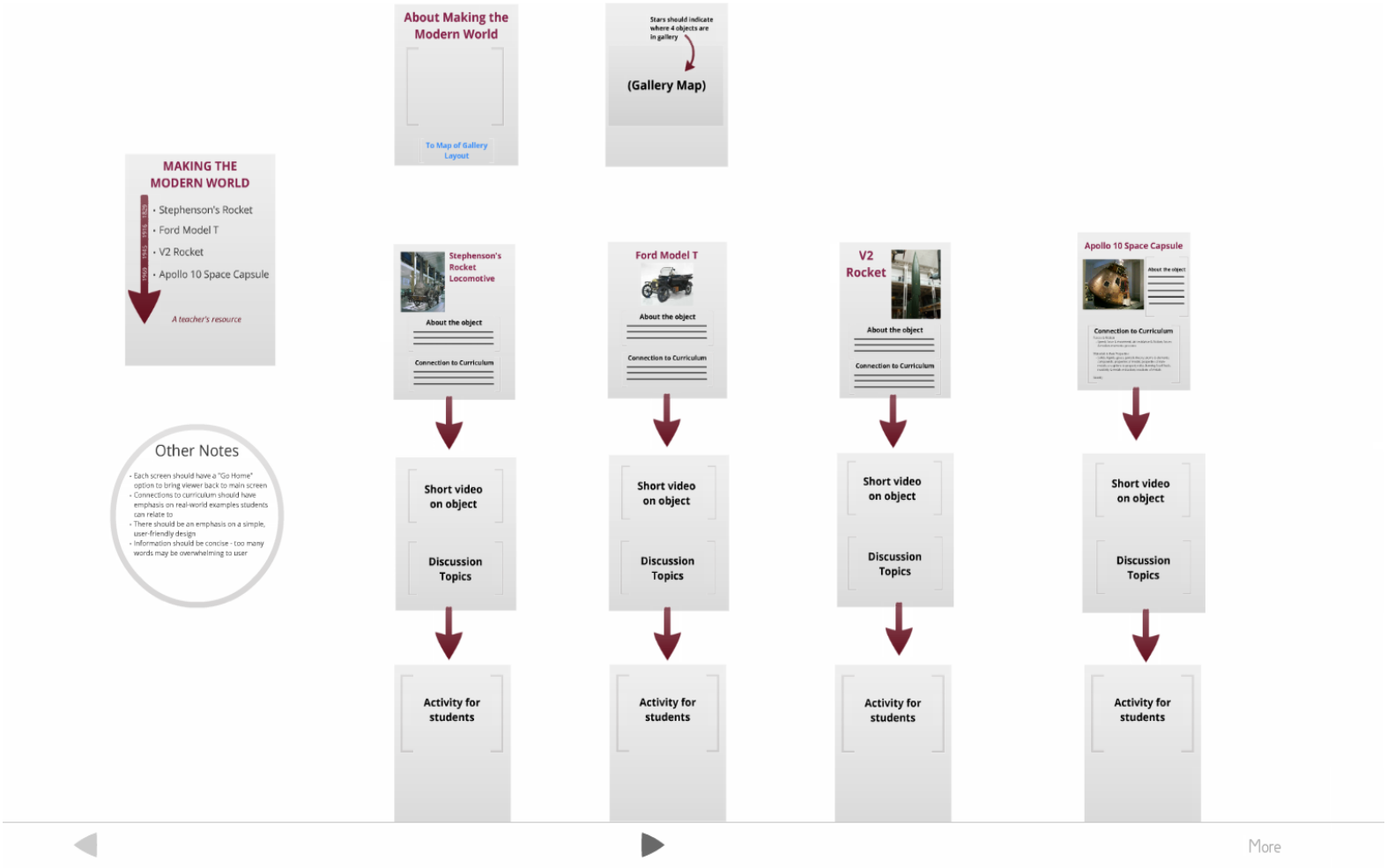


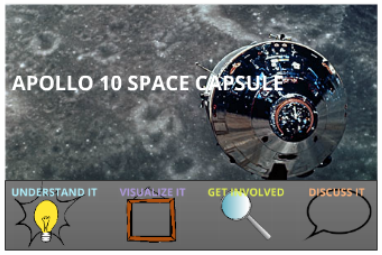
Figure5: The 10 most visited science centers worldwide (Walhimer, 2012).

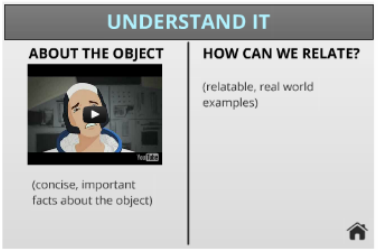
The overarching purpose of the Science Museum since its inception was technical education. However, beginning in the 1960s, the emphasis of the museum started to shift more towards preserving historical artifacts and educating visitors about them and their social context. This new approach was implemented through the development of exhibits in which visitors discover how things work interactively with their hands rather than passively by reading exhibit descriptions. One of the most popular exhibits has been the "*Launch Pad*" which first opened in 1986 (Museum of Science, "Museum history," n.d.). Still throughout all its changes, as the UK's most popular destination dedicated to science, technology, engineering, medicine, design and enterprise, the Science Museum has maintained its mission to help its visitors make sense of the science that helps shape their lives. The museum serves its purpose to play an integral part in changing the world's relationship with science and technology.

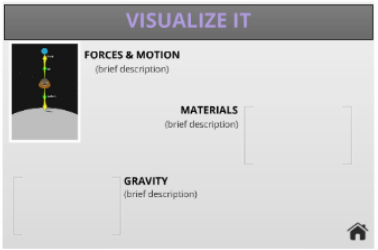
Appendix B: Concept Design 1 in Prezi



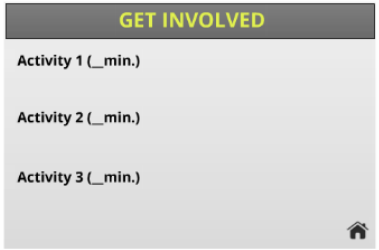
Appendix C: Concept Design 2 in Prezi







*Different visual aids for KS3 science topics -- interactive?



*Different activities for students (ex: Mystery Object Search)
*Indicate estimated length of each activity

*Short discussion points for teachers (not too detailed --> enough to spark conversation)

Appendix D: Student Observation Sheet

Date: **Interviewer:** **No.**

Direction of approach: Front right / Front left / End

Things to look out for:	**Observations:**
Observations student behavior Interaction with space: • Interact with exhibits? Which ones? (Pay special attention to app objects) • Engaged? (>5s) • Glance at exhibits? (<5s) • Watch others use exhibits? • Use exhibits in groups? • Use exhibits as individuals? • Dash around gallery? Social interaction: • Interaction between teacher and students? • Interaction between peers whilst using exhibits? • Calling others to come to exhibits? • Calling others away from exhibits? Take photo? Points to anything? Student reactions and behavior: • Body language • Facial expressions • Comments • Level of participation • Any audible complaints? What objects do they focus on?	

Appendix E: Teacher Observation Sheet

Date: **Interviewer:** **No.**

Direction of approach: Front right / Front left / End

Things to look out for:	**Observations:**
Observations of teacher behavior Interaction with space: • Interact with exhibits? Which ones? (Pay special attention to app objects) • Watch students use exhibits? • Use exhibits with students? • Use museum resources? Which ones? How well do they seem to work? • Seem to understand logistics? • Dash around gallery? Social interaction: • Interaction between teacher and students? • Calling others to come to exhibits? • Calling others away from exhibits? • Do teachers start discussions? • Do they appear to be doing activities with their students? Points to anything? Student / Teacher reactions and behavior: • Body language • Facial expressions • Comments • Level of participation What objects do they focus on?	

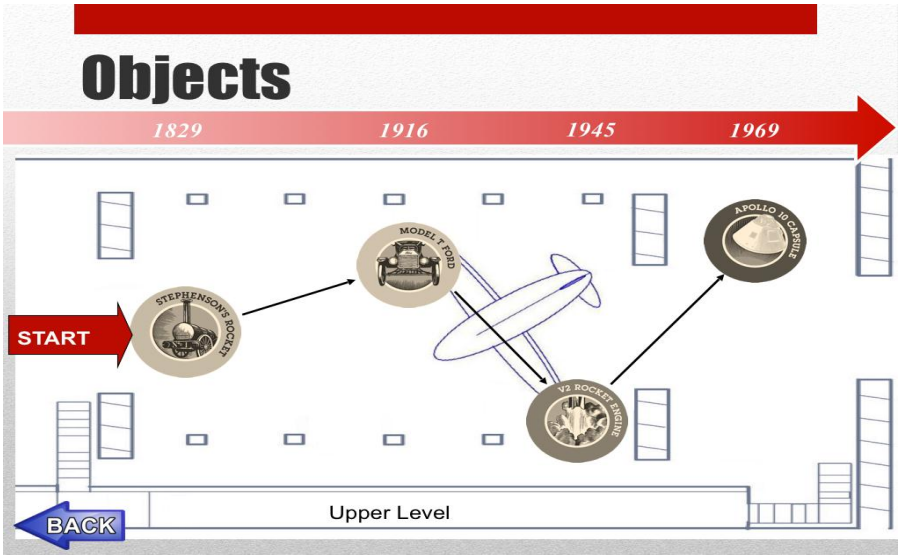
Appendix F: Prototype 1 Screen Shots

Intro Page

Tutorial Page

Home Page

Gallery Map

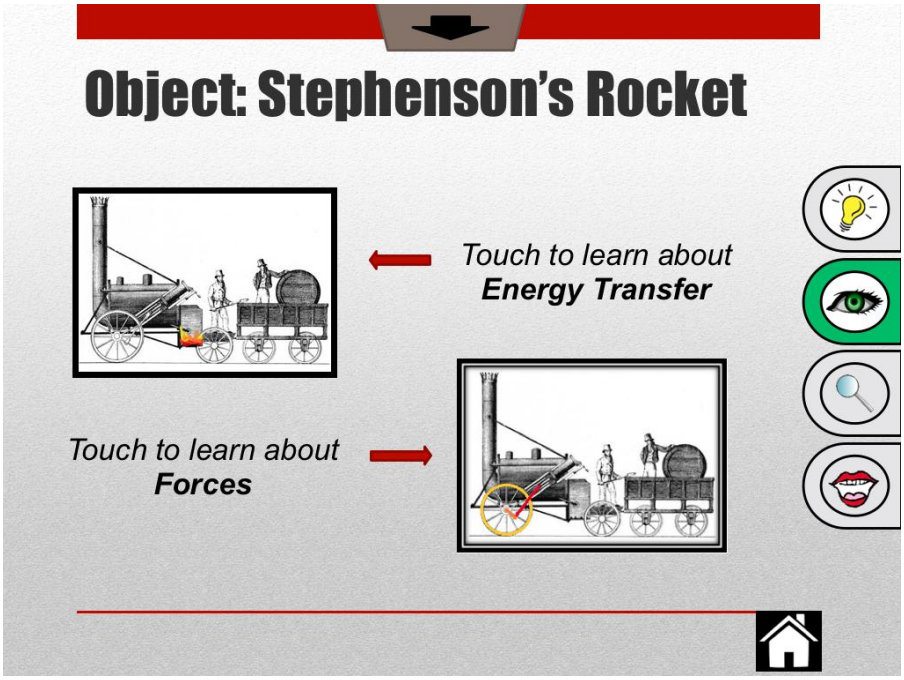


Example Object Home Page

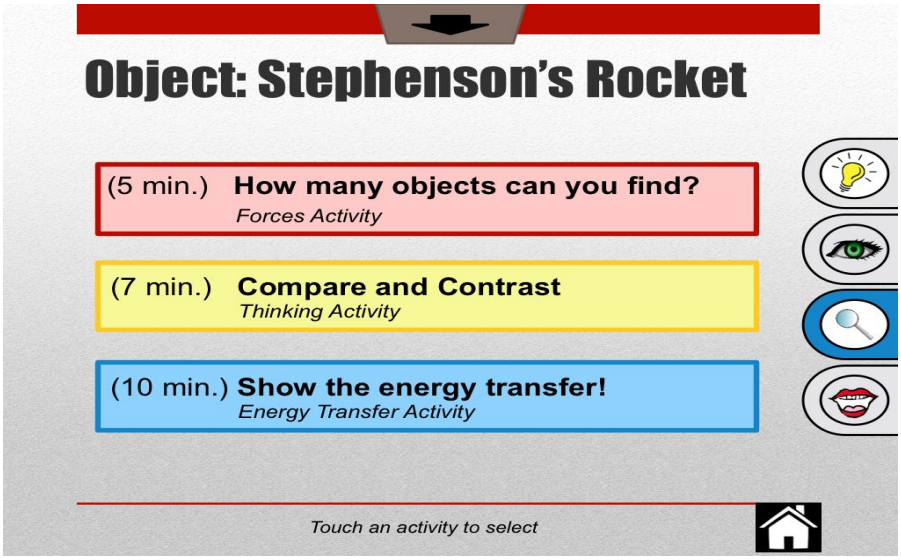
Example Object Information Page[2]

[2] This page is linked to the *Object Info* tab seen in the *Example Object Home Page*

Example KS3 Visual Aids Page[3]



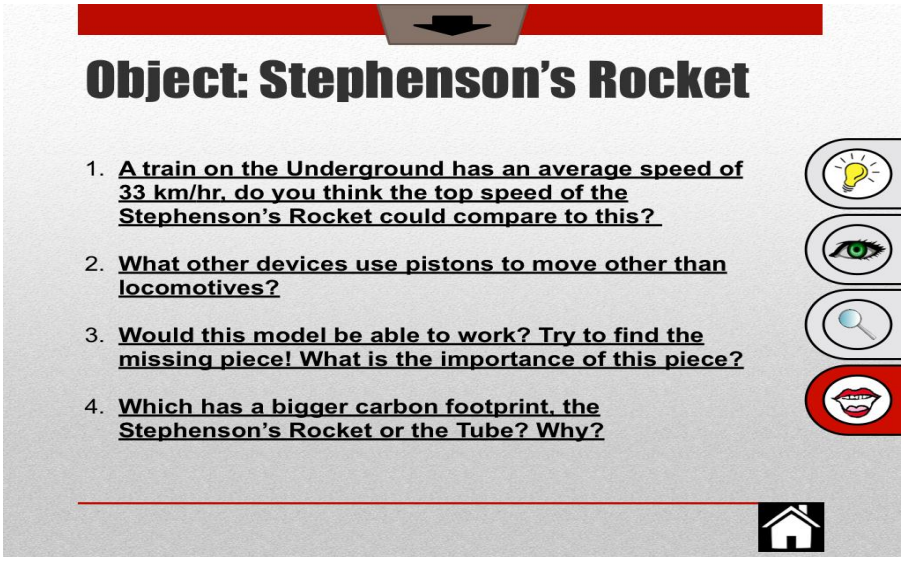
Example Activities Page[4]



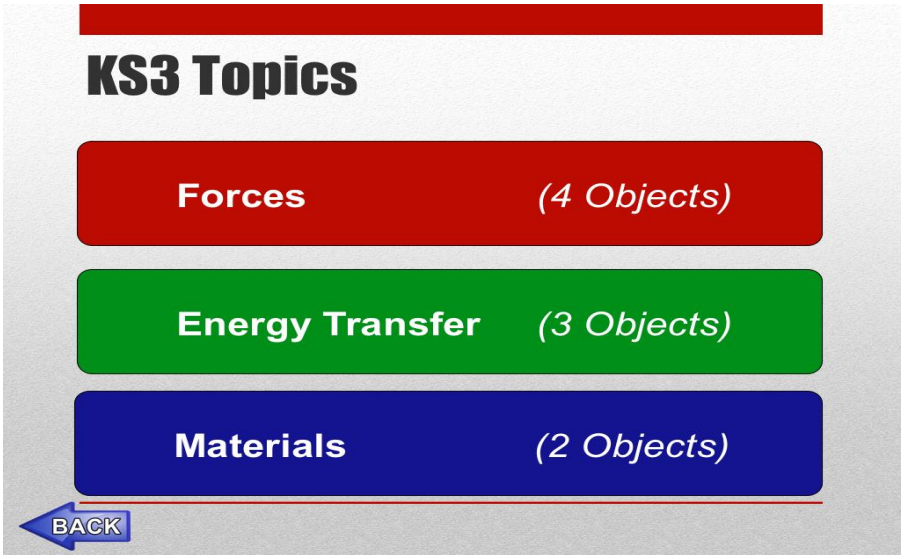
[3] This page is linked to the *KS3 Visual Aids* tab seen in the *Example Object Home Page*

[4] This page is linked to the *Activities* tab seen in the *Example Object Home Page*

Example Discussion Q's Page[5]



Example KS3 Topics Page[6]



[5] This page is linked to the *Discussion Q's* tab seen in the Example Object Home Page
[6] This page is linked to the *KS3 Topics* tab seen in the Home Page

Appendix G: Prototype 1 Testing Aims & Objectives

Testing: 6 KS3 Science Teachers

Focusing on:

- Usability
- Functionality

Aim

Does the target audience understand the function and purpose of the application?

Objectives

- Can the teacher find the objects in the gallery?
    - Does the gallery map serve its purpose?
    - Is it easy to follow?
- Is the app easily navigated?
    - Does each section seem to flow smoothly one to the other?
    - Is the design simple and user-friendly?
- Is the design museum-specific and not something that could be used just off-site?
- Does the teacher clearly understand the application's purpose?
- Does the teacher feel that the application successfully bridges the gap between the curriculum and the gallery?
- Does the teacher clearly understand each component (e.g., "understand it")?
    - Can they understand the purpose before following the link?
    - Are the titles self-explanatory?
    - Did they click each link? Why?
    - Did any of the pages seem overwhelming at first glance?
- Are the teachers motivated to use it?
    - Would it help them to promote discussion, engage students and lead activities?

Appendix H: Prototype 1 Testing Questions and Observation Sheet

Preamble

- We are developing a new application for teachers to use while in the *Making the Modern World* gallery with their students
- Very preliminary stage, still in the beginning stages of development
- No right or wrong way to use this app
- We are not testing you as a teacher, we're just looking at the functionality of the app itself
- Please don't hesitate to give us your most honest and critical answers – we won't be offended!
- Please feel free to talk out loud as you use the app so we can get a better idea of what you're thinking
- We will be writing down what you tell us and what we observe, but it will be confidential. The data collected from this visit will only be used anonymously in our report.
- We will start with preliminary questions, followed by an accompanied visit through the gallery. Here you will be able to freely use the app for a while before we ask you some questions. We will end with more questions at the end, which may take a little longer.

Pre-Questions

1. Which, if any, of the following devices are you familiar with using?

   1a. Smart phones

   - iPhone
   - Android phone
   - Blackberry
   - None
   - Other _____

   1b. Any other device with a touch-screen interface

   - iPod touch
   - iPad
   - Tablet (Nook, Kindle)
   - None
   - Other _____

   □ Probe: Are you comfortable with the touch-screen interface?

   - On a scale of 1 (not comfortable, never use) to 5 (very comfortable, use daily)

     1 2 3 4 5

2. Have you used an iPad in the classroom (specifically as a learning tool)?

   Y / N

3. Have you been to the Science Museum before?

Y / N

- ☐ Probe: (If yes), when?

4. Have you brought a school group (i.e., KS3) to the Science Museum before?
   Y / N

5. (If yes to #4) Did you prepare any educational materials prior to visiting the Science Museum with students? (i.e., pre visit or post-visit activities)
   Y / N

   - ☐ Probe: (If yes) do you feel this helped you while in the museum with your students?

6. Have you specifically visited the *Making the Modern World* Gallery either by yourself or with students?
   Y / N

7. Would you be interested in using a mobile guide for a tour in a museum?
   Y / N

   - ☐ Prompt: Would you use a mobile application as a guide while in the museum, say on a mobile phone or iPad?

   - ☐ Probe: What makes you say that?

8. What are you expecting to get out of this app?

Observations

Interview Questions

- What do you think this link will take you to?
- How did you know what to do?
- What made you choose that button over the others?
- Can you orient yourself in the gallery using the map?
- What are you looking for?
- What are your initial reactions to this page?
- Can you imagine yourself using this [activity, discussion point, visual aid] with your students?
  - Probe: Can you tell me in what sort of ways?
- I noticed you didn't click on X, can you tell me why?
- What do you think would happen if you clicked X versus Y?
- Would you be confident enough to reiterate this to your students without reading it previously?
- How would you use that activity/question?

Things to look out for

- Clicking where there's no link
- Clicking without reading text
- Facial expressions/body language
- Do they read the text fully before moving on?
- Did they skim the page or read/play it fully?
- Initial reaction
- Does it look like they're making connections between the iPad and the object? (Glancing back and forth)
- Did they read the object labels?
- Are they distracted?
- Did they skip or avoid one section?

Intro Page/Tutorial

- Tutorial: Read, skim, skip?

Objects/Topics Main Page

- Which category did they pick first on the home screen? O / T

Gallery Maps

- Do they turn the iPad to use the map? Y / N

Stephenson's Rocket (1 2 3 4)

Object info

Visual Aids Activities Discussion Q's
Model T Ford (1 2 3 4) Object info Visual Aids Activities Discussion Q's
V2 Rocket (1 2 3 4) Object info Visual Aids Activities Discussion Q's

Apollo Capsule (1 2 3 4)
Object info Visual Aids Activities Discussion Q's
OTHER

Exit Questions

9. What is your overall impression of the app?

10. What did you like about this app?

11. What did you dislike about this app?

12. Did you prefer using the Objects or KS3 Topics menu?
    Objects / Topics

    - □ Probe: Why is that?

13. What do you think you would gain from using the app? How could it help you?

14. Is there anything that really confused you?

Y / N

□ Probe: (If yes) which aspects?

15. Do you think the app caters to a range of KS3 students, abilities, learning styles, and interest levels?

Y / N

□ Probe: Could you explain why you feel this way?

16. Did you see connections between the curriculum and the app's content?

Y / N

□ Probe: (If yes) can you expand on that and tell me examples you saw in the app?

□ Probe: (If yes) do you think the app would aid you in delivering these curriculum links to students?

Y / N

□ Probe: What makes you say that?

17. Was there anything new or surprising to you that you found out by using this app? (About the objects, discussions, activities, etc.)

Y / N

□ Prompt: Did you learn something new about the objects through the discussions, activities, or visual aids?

Y / N

□ Probe: Could you expand upon this?

18. Do you think your students will be engaged in:

The activities? Y / N

□ Probe: Why is that?

The discussions? Y / N

□ Probe: Why is that?

The visual aids? Y / N

- □ Probe: Why is that?

19. Within the object pages, which order would you use the different sections?

20. How do you think you would find sharing the visual aids (videos, pictures, etc.) with your students?
    - □ Probe: What makes you say that?

21. Did any of the categories stand out to you?
    - □ Probe: Do you prefer visual aids, discussions, activities, or object information?

22. Can you see yourself using this type of resource in future school group visits to the Science Museum?

    Y / N

    - □ Probe: Why is that?

    - □ Probe: (If yes) how do you think you would you use the app with your students?

23. Is there anything that might prevent you from using this resource with your students?

    Y / N

    - □ Prompt: The app itself?
    - □ Prompt: The activities?
    - □ Prompt: Practicalities?
    - □ Probe: Why is that?

24. Did you find the gallery map helpful?

25. Did you find the tutorial page helpful?

    Y / N

    - □ Probe: Was it overwhelming at first glance?

      Y / N

    - □ Probe: Did you read all of the information on it?

Y / N

- □ Do you think you would read it while on a museum trip?

26. What did you think about the design and layout of the app?
    - □ Prompt: Did you find the design simple or overwhelming?

27. Did you find the overall format confusing? Y / N
    - □ Probe: Was it easy to navigate? Y / N

28. Are the titles self-explanatory?

Y / N

29. Is this app something you can see yourself using in the classroom?

Y / N

- □ Probe: Do you think it's more suitable for a museum setting?

30. Is there anything specific you feel we can do to improve this prototype?

Appendix I: Prototype 1 Pre-Question Spreadsheet

Questions 1 – 4

1	Sheet Number	Date	Observer	M/F	Age Bracket 1=16-18 2=19-25 3=26-35 4=36-50 5=50+	Which smart-phone are you familiar with?	Which other touch-interface?	Comfort with touch-screen on a scale of 1(no)-5(yes)	Used iPad in classroom?	Been to Science Museum before?	When?	Brought a school group to Science Museum?
2						Q1a	Q1b	Q1c	Q2	Q3	Q3a	Q4
3												
4	1	22/05/2012	JL & DM	F	4	Android	Looking into getting samsung tablet	5	N	Y	Lunch box training	Y, 11-12 y.o sleepover and workshops
5	2	22/05/2012	JL & DM	F	3	iPhone	None (only have regular iPod)	5	N	Y	brought friends 2-3 mo. ago	Y (KS3 year 8)
6	3	22/05/2012	LS & BZ	F	3	Android	iPod touch, iPad	3	N	Y	3 months ago, independently	Y
7	4	24/05/2012	LS & BZ	F	2	iPhone	iPod touch, iPad (uses them but doesn't own one	4	N	Y	loads of times, 3 times per year, with school groups and individually	Y (younger groups)
8	5	26/05/2012	JL & DM	F	4	All	All	5	N (b/c they have to provide their own. could use interactive boards w/iPads, that way kids could use the app w/out breaking iPads)	Y	April (for lates)	Y (KS3 and older)

Questions 5 – 8

Did you prepare any eduactional materials prior to visit?	Visited MMW? By yourself or with students?	Interested in mobile guide for a tour in a museum?	What do you expect to get out of this app?
Q5	Q6	Q7	Q8
N	Y, by herself	Y	Feel I've imputted to the museum, inspiration of ideas for visits, know how science works
N	Y (both)	Y (interesting to find more info about objects)	quick info, clarity, interesting facts, interaction
Y	Y, individually	Y	No idea
Y(Designed activities/quizes for them and let them explore than chat/report back to her	Y (both), but not with KS3 students	possibly if they were on iphones or andriods.	no idea about it
Y (booklets for diff galleries, used to get materials from ScM website. Helpful - kids liked interaction)	Y (both - KS3 & up to age 16, learn about objects in school (i.e., Stephenson) & they like seeing them in person. Kids are attracted to these objects and style of gallery)	Y (very useful, "brilliant" esp. if on iPhone/Android (best for students to use). Better to have info on a gadget than in a book (they always have phones, take care of them), it would get used - could find everything immediately, public could use it too b/c they look at website beforehand anyway)	links to website for info on large objects

Appendix J: Prototype 1 Post-Question Spreadsheet[7]

Questions 9 – 15

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sheet Number	Date	Observer	M/F	Age Bracket 1=16-18 2=19-25 3=26-35 4=36-50	Overall impression	Like	Dislike	Objects/KS3 Topics	Were the previous expectations met?	What would you gain? How would it help you?	Anything confusing? If yes, what?
2						Q9	Q10	Q11	Q12	Q13	Q14	Q15
3												
4	1	22/05/2012	JL & DM	F	4	Loved it	Straight forward to use, gallery map, timeline, icons used	iPad felt heavy after a while	Objects, bc the KS3 stuff comes up anyways		good way to motivate students, brings science to the students' level, challenges bright students, something visual	N, but would like to play with it first to get a feel for it
5	2	22/05/2012	JL & DM	F	3	very good - fantastic tool (if students are well behaved)	teaching w/out prior knowledge, activities, instant info, fun facts, side buttons, object info pages	underlining on questions, lack of ranking, visually appealing to teachers but not kids	Topics (would focus on 1 topic per visit, no confusion about linking topics)	N/A	elicit interest from students	N (just needed more time to explore - simple design. Expected timeline to scroll)
6	3	22/05/2012	LS & BZ	F	3	Good, took time to figure out. But overall simple and teacher-friendly.	Doesn't involve writing, giving more freedom and independence. Gives me ideas, good layout	Confusing at first, didn't understand what objects option meant	Topics because I could link back to national curriculum	N/A	It's good for trying to get them to make a link	Yes: objects option and gallery map
7	4	24/05/2012	LS & BZ	F	2	she liked it, really like the Discussion Q's because it required thinking. Also she felt it would make the whole museum trip much more meaningful. Really nice, would definetly use it.	Easy to use, clicking was straightforward. Big text, easy to find information.	The map needs more orientation. Airplane wing is orientated incorrectly? KS3 visual aid is simplified info, no need for it.	Topics because teachers need to have an aim in mind when visiting the museum or its just a nice day out.	n/a	From the discussion Q's, the thinking bit will definetly help them. Its nice to have a root from something.	Yes: Difference between topics vs. objects. If she were with a group she would more pressured and more likely to be even more confused and not use it at all.
8	5	26/05/2012	JL & DM	F	4	"absolutely excellent", would download immediately & use it all the time, so many uses (even outside of museum)	open ended q's, the way to activities are broken up, broken down into diff topics, chronological but not too structured (could choose own path), open ended, range of basic to advanced, airplane on map, user friendly, easy language for kids of all ages, tutorial page (lays everything out nicely), color coding, it's almost a science museum trip in an app if you can't make it to the museum, social/moral/cultural/historical links, explains physics easily (generally not taught well in schools)	only little things (every picture zoomed in, diff background color) - can't find any other faults	objects (could cover a lot of bases - likes the option of both & could see herself using either. Understood the purpose! "Topics" is good if focusing on one topic during visit, "Objects" is good for general science trip)	n/a	she would gain time! (it's done for her, no worrying about preparing or forgetting things - info is here & instant. No pre-trip needed, which takes up a lot of time)	N (so well put together, literally can't go wrong wit, everything is so easy)

[7] The color coding is as follows: (at the top) Engagement, Motivation, and Usability; (in spreadsheet) Positive, Neutral, and Negative.

Questions 16 – 19b

M	N	O	P	Q	R	S
Does the app cater to KS3 students?	**Connection between curriculum and the app's content?**	**Would the app aid in delivering curriculum links to students?**	**Anything new or surprising you found out?**	**Learn through the q's, activities or vis aids?**	**Will your students be engaged in the activites?**	**Will your students be engaged in the discussions?**
Q16	**Q17**	**Q17a**	**Q18**	**Q18a**	**Q19a**	**Q19b**
Goes above KS3., wants more simple questions, not everyone would be able to answer q's, definitely would hold attention	Y, justifies assesment for learning, students can choose there own learning journey	Y	Y, loved info about the objects, loved the q's	Y, lots of info to digest, info abou the objects widens knowledge	Y, would be very engaged if they each had an iPad	Y, makes links between the real world and inventions
Y (& KS4 - forces in KS3 = simple diagrams, forces in KS4 = inertia, speed/velocity. Even she learned from it)	Y (all sections)	Y (activities avail. that she might not have thought of, random facts to share)	N (simple, straightforward)	Y (random object info)	Y (more so if they were on their phones)	N (only if they were well behaved)
Yes	Yes. Forces: key words that link directly to curriculum. Materials: gets them to think about the uses. Investigative skills in science: How Science Works unit	Yes: it gave me lots of ideas	Yes: I learned more than ever have coming here before	Mostly activities and discussions	It depends on the delivery and how the teacher interprets it.	It depends on the delivery and how the teacher interprets it.
Yes. Questions are really chalenging. Requires thinking and has a good range of long/short and hard/easy questions.	Yes. Energy: she saw the key words that linked to everything in terms of Kenetic Energy and also the main forces.	Yes: Covering the correct topics and good range of topics	Yes, new things from the object info.	Activities gave her different ways of thinking. "Oh yeah, cool. I didn't think about that."	Yes	Yes
Y (b/c of open ended q's - gets them involved, everyone would enjoy experience. Higher level could be pushed farther. No need to limit app to KS3 - adaptable info)	Y (absolutely - covered all things that were necessary)	Y (definitely! Good for pre- and post-visit in classroom (could use on board), social/moral/cultural links, kids can show leadership skills & teamwork or independence)	Y (learned a lot about V2, didn't know much before. Liked background info & the links to history. Justifies trip to museum, covers a lot of subjects/topics)	Y (see 18)	Yes (so many options, could hit all levels. Interesting! Things that will make them think)	Yes

Questions 19c – 26b

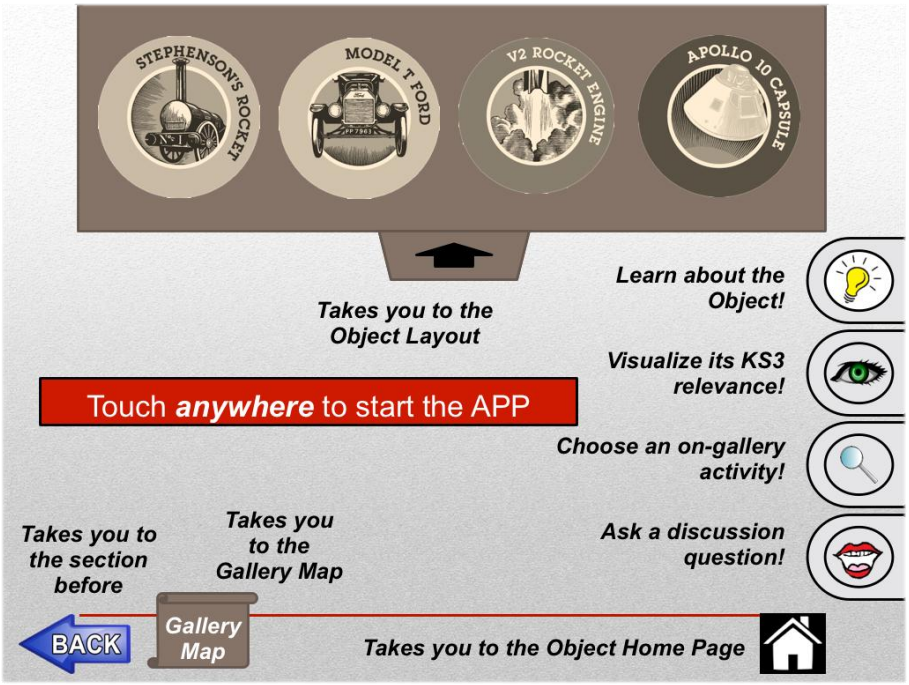
T	U	V	W	X	Y	Z	AA	AB	AC	AD
Will your students be engaged in the visual aids?	**Would you order the object page differently?**	**How would you find sharing visual aids with your students?**	**Did any of the catagories stand out?**	**Can you see yourself using this type of resource in future school group visits to the Sci Museum?**	**How would you use the app with your students?**	**What might prevent you from using this resource?**	**Was the gallery map helpful?**	**Was the tutorial page helpful?**	**Was it overwhelming?**	**Did you read all the info?**
Q19c	**Q20**	**Q21**	**Q22**	**Q23**	**Q23a**	**Q24**	**Q25**	**Q26**	**Q26a**	**Q26b**
Y, for the visual learners	N	Show them visuals, have them apply to objects, after lesson follow up	Likes visual aids, likes activities	Y, this is the way forward	small groups-pass it around, explore it; bigger groups-not everyone would be able to see it; would use 1-1 if they didn't understand	Y, having enough iPads for a bigger group, have each chaperone use one	Y, overwhelmed at first by gallery, couldn't find 1st object, its fine when once you find the first	Y, but would love to see it before visiting	Y	N, overwhelmed and excited to start the app
N/A (pictures need to be bigger, better for well behaved kids)	good order, would use it this way	wouldn't use videos (prefer to have them focused on object)	loved layout of activities (big, colorful), text too small on discussions	Y (w/info on SciM website to look at beforehand)	would rather use it at another school, but the questions are interesting	not having info before, too much focus on app rather than object - but many advantages, very helpful	Y (definitely - very clear)	Y (should have directions in box w/an arrow)	Y	skimmed
It depends on the delivery and how the teacher interprets it.	Yes: I would put activities and discussions first, then information and visual aids.	I think it would be great because they could go up and have a look at it and come back again. It gives them a different dimension.	Yes, the discussions and the activities were really great. But it all needs to be there.	I would personally never bring students here, but it would be great for teachers to come ahead of time and have a look around the gallery.	N/A	N/A	Yes, once I managed to orient myself.	Yes, after I actually read it.	No	No. I thought it might be a tutorial about the museum.
No, would not show them, can't see it. Not big enough to show to students.	the same, they are fine.	She wouldn't because the diagrams are boring and too small to show the iPad to a whole group of students.	Discussions definetly stood out most. Really good.	Yes, it's a nice questioning technique rather than just looking at it. Students have to think about it.	She would use the discussions questions with her students.	No, other than the fact that its not available. :)	Yes and no. You have to have the map, but it needs to be correct.	Yes, need to have it. But didn't really look at it until the end.	No, its just she didn't follow the instructions.	No.
Yes (allows them to imagine it, you can see how they're thinking about it, real world connections. Even good for visually impaired - pics large enough to see when object is too far away)	no (likes the order - logical)	clicked on wheel, imagined showing to students (pixelated, but clear enough to see it). Would pass it along to students or hold it up to show - depends on size of group. Could have them use on phones. Could use it on writeboard back in classroom, even use for HW q's	discussions (really good!), activities is 2nd fav., visuals & info could be used in classroom	Y (accessible for everyone, even TA's - ccould convince kids they know everything. Everything is there for you! Could show students app too)	opportunities are endless! Would take suggested route to do activities & disc. Q's, then link back to classroom (have map on board, split them into groups, review the trip)	N (there's no reason a school wouldn't use it, unless cost was an issue. But there are so many other technologies avail. (not just iPads) it wouldn't be a problem. Typical to have iPad provided by school)	Y (brilliant, very useful, has key objects from gallery)	Y (helpful to have it there, but most scientists would rather play around w/app first. She doesn't prefer to use instructions, but some do so it's good to have. Good for those not comfortable w/technology)	N (really clear to use. Very simply written, couldn't go wrong)	N

Questions 26c – 31

AE	AF	AG	AH	AI	AJ	AK	AL	AM
Do you think you would read it on a museum trip?	**Thoughts on design and layout?**	**Simple or Overwhelming**	**Was the overall format confusing?**	**Was it easy to navigate?**	**Are the titles self-explanatory?**	**Is this something you can see yourself using in a classroom?**	**Is it more suitable for a museum setting?**	**Improvements?**
Q26c	**Q27**	**Q27a**	**Q28**	**Q28a**	**Q29**	**Q30**	**Q30a**	**Q31**
Y, would wantt at home first	Liked it, gallery map, loved dates, not too much info, tutorial a bit too much to take in, kept it simple and clear	Simple	Y, at first, text on title page was confusing people would probably go by objects rather than topics	Y, map maybe first page	Most of the them, didn't know it was called MMW, image of gallery on first page	Y	Y	SCN levels to cater for all, audio --> literacy and visual reasons, pictures who forces drawn, have teachers play first, android
N/A	didn't notice tab feature (had to point it out - someone who knows iPads better may notice it, boring color), should have diff. font, needs better quality pics (i.e., wheel), too many colors on pictures	simple	N	Y	Y	Y (would work as well like a ppt.)	would use less hands-on material in museum (i.e., materials) & more hands-on activities in classroom (i.e., not forces)	arrows on tutorial, less colors on diagrams, keep text simple/to a min., better quality pictures (esp. if showing to kids), rank act./q's based on level, more animations & less static images (i.e., combustion), bigger pictures (everypic should be able to zoom in to show kids - ex. pic of capsule w/moon), larger text on discussions, less info on SR forces page (teacher should already know that), thicker arrows on force diag.
Yes, if I had tcgo through the tcorial first.	It's pretty self-explanatory once you get the hang of it. I like the colors.	Pretty simple.	No.	Yea, it was pretty easy to navigate. It probably would have been easier if I had read the tutorial first.	Yes, though I didn't read them at first, I just sort of figured it out for myself.	Yes, some activities would be great for in the classroom.	Yes	I think some activites need tweaking, maybe adding some key facts to make kids interested. I think questions should be phrased as multiple choice because it's more interactive and can be a bit competitive.
Possibly yes;she would have more responsibility;so she would try to read it more carefull;	Very nice. Neat, colorful, easy and clear.	simple.	No. It was easy to understand at the end.	Yes. It was pretty easy to navigate.	Yes.	Yes.	Yes, more suitable for museum. It would be great to use in gallery and she could do some great follow up in classroom.	No she doesn't think so. It took her a min or 2 to figure out how it would work.
Y (could readon the way to museum or while students are putting bags in cages	Literally can't go wrong, so simple to follow. Change background color. Dyslexic friendly - colors on key words, consistent color coding, rounded font. Didn't notice objects tab at first, but thinks it's really neat (good idea, easier than going back to map every time), user friendly (anyone could use it). The way it's broken down makes so much sense	simple	N	Y (very!)	Y (couldn't have made them any more simple)	Y (absolutely, could put on interactive boards so kids could use them, activities are broken up so you could assign taks by color)	Y	Change background color to something buff (easier on eyes), change to UK spelling. Look at "progress program" for levels. Include footnote on discussions to click Q for answer. Would like audio info for visually impaired. For further development --> pictures of side cabinets to see objects, tap pic for info. Link to upper level to see what's up there (put on map). Could also use for trainee teachers to show them how to plan a museum trip.

Appendix K: Prototype Tutorial Development

This appendix describes the transformation of the tutorial page in the prototype development stages. The tutorial page seen in the figure below was developed for Prototype 1 to aid teachers in understanding certain features of the application and their functions. It was placed at the start of the application so each teacher had to look at it before continuing to start the testing.

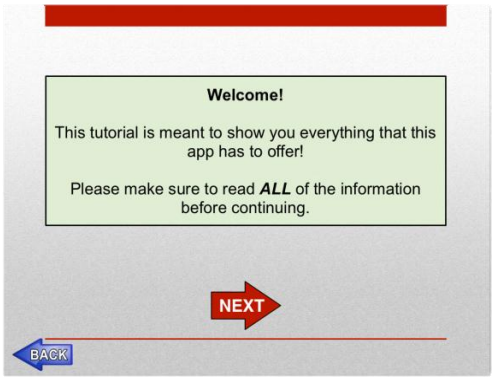
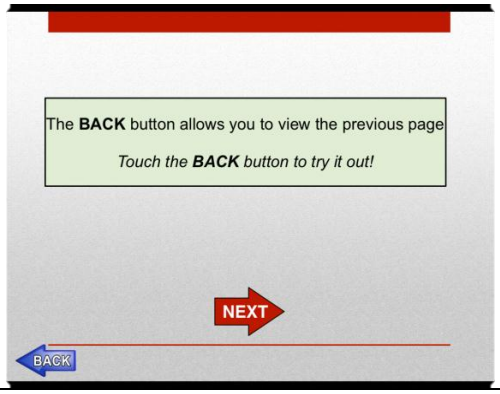
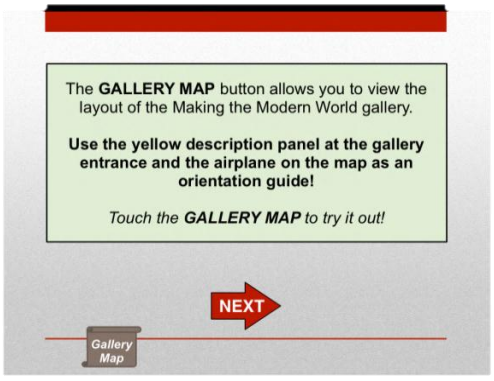
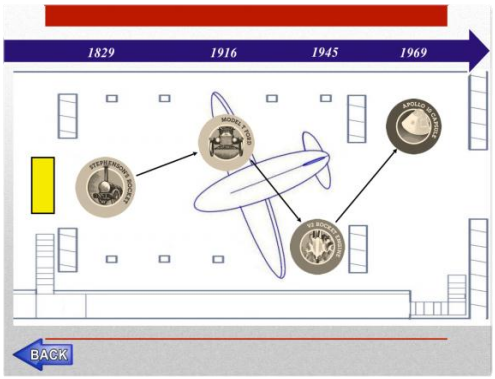


Based on results from the first testing, it was learned that most teachers skipped the tutorial or did not read all the information, and thus struggled initially to use the application. To avoid this from happening, the tutorial was modified into a step by step process in Prototype 2.

The follow table shows the progression of the tutorial and how the individual pages are linked together. (Note that "L" is short for "last viewed page" and is linked to the "back" button.

Current Page	Pages directly linked to current page
1	2, L
2	3, L
3	4, 6
4	L
5	6
6	7
7	8, 9
8	L
9	10, 11
10	L
11	L

The following table provides the images of the pages of the tutorial developed for Prototype 2 based on the feedback of Prototype 1 testing.

<table>
<tr>
<td>1
 
</td>
<td>2
 
</td>
</tr>
<tr>
<td>3
 
</td>
<td>4
 
</td>
</tr>
</table>

5

The **HOME** button will take you to the home page of the object you are viewing.

If you are on the home page, the **HOME** button will take you to the home page of this app.

NEXT

6

The **SIDE TABS** allow you to view information, KS 3 content, activities, and questions about the objects.

Learn about the Object!

Visualise its KS3 relevance!

Choose an on-gallery activity!

Ask a discussion question!

NEXT

7

ZOOM in on pictures and diagrams that have a *magnifying glass* to show to your students.

Touch the picture to try it out!

NEXT

8

BACK

9

You can touch the activities to get more information.
Touch the activity to try it out!

(5 min.) **Life as an Astronaut**
Thinking Activity

You can touch the questions to get the answers.
Touch the question to try it out!

1. **Which would win a 100m dash in the 2012 Summer Olympics: A Ford Model T, a lion, or Usain Bolt?**

FINISH

10

Object: Model T Ford

Which would win a 100m dash in the 2012 Summer Olympics: A Ford Model T, a lion, or Usain Bolt?

1. Lion (top speed of 81 km/hr)
2. Ford Model T (top speed of 72 km/hr)
3. Usain Bolt (top speed of43 km/hr)

BACK

11

Object: Apollo 10 Capsule

(5 min.) **Life as an Astronaut**

The three astronauts on this mission lived in the Apollo capsule, which is only 3.63 meters long, for 8 days. Have your students stand in groups of 3 within a 3x3 meter space. Could they imagine living in this small space for days at a time? What other challenges do astronauts face both pre-flight and during the missions?

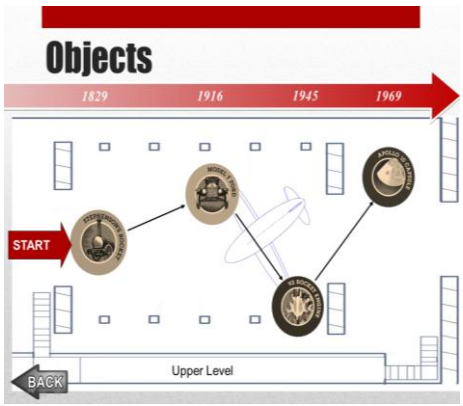
BACK

Appendix L: Prototype Home Page and Gallery Map Development

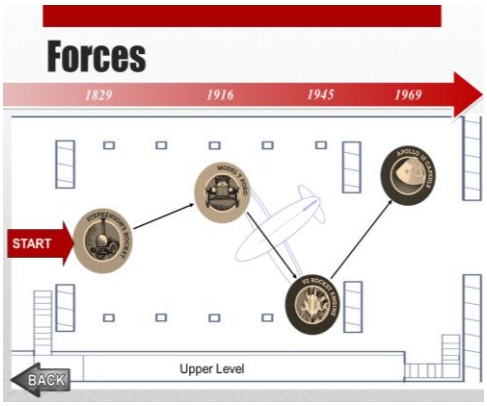
This appendix describes the transformation of the gallery map in the prototype development stages. The purpose of the gallery map page was to help the teachers orientate themselves in the museum floor since many are not very familiar with where specific objects can be found in the museum floor.

Prototype 1 Gallery Maps

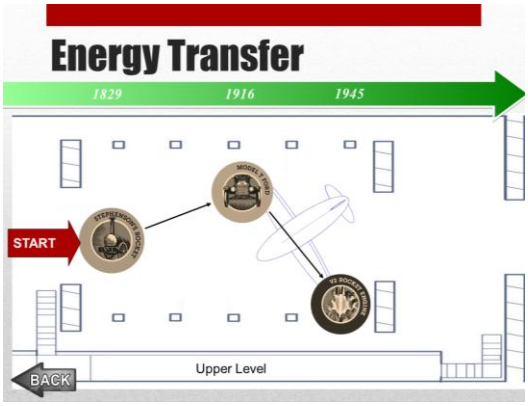
In Prototype 1, there were *four* slightly different versions of the gallery map; teachers were able to access the content of the app in Prototype 1 via two pathways: "Objects" and "KS3 Topics," this can be seen in screenshot 1 in the table below.

<table>
<tr><td colspan="2">1) Home Page
 
</td></tr>
<tr><td><u>"Objects" Path</u></td><td><u>"KS3 Topics" Path</u></td></tr>
<tr><td>2) "Objects" Map
 
</td><td>3) "KS3 Topics" Selection Menu
 
</td></tr>
</table>

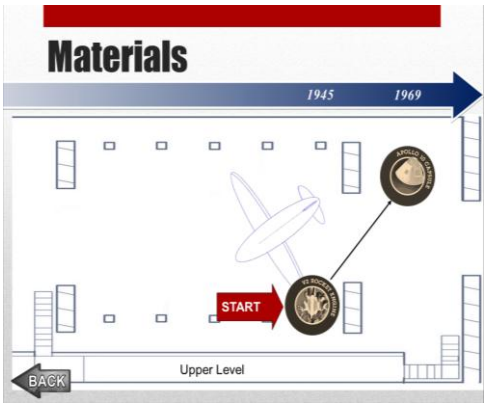
4) “Forces” Gallery Map



5) “Energy Transfer” Gallery Map



6) “Materials” Gallery Map



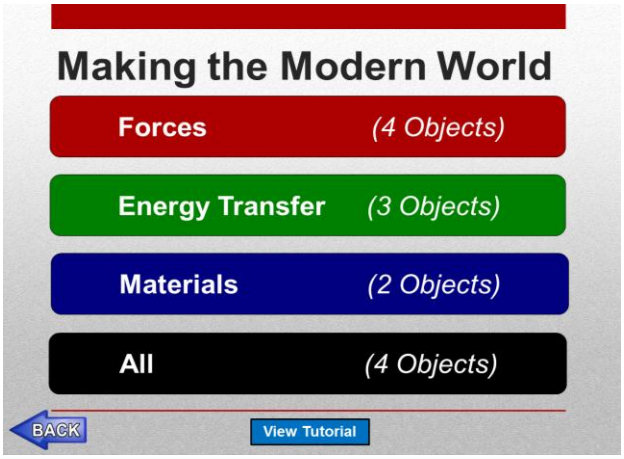
If teachers choose the "Objects" options to begin the tour, then we can see screenshot 2, "Objects" Maps, as their gallery map. This screenshot can be seen on the left hand column in the table above.

If teachers choose the "Topics" options to begin the tour, then it would take them to the right hand column of the table above. Screenshot 3, "KS3 Topics" selection menu, teachers would be taken to this page where they could choose from the following 3 topics: Forces, Energy Transfer, and Materials. Screenshots 4, 5, and 6 are screenshots of the specific gallery maps for the three individual KS3 topics.

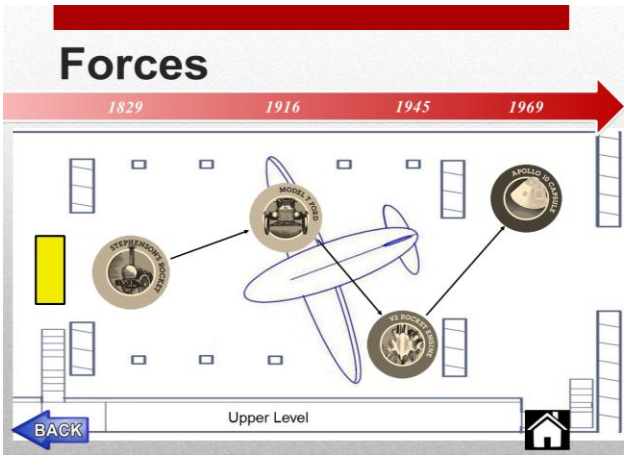
Prototype 2 Gallery Maps

In Prototype 2, one of the changes that we made was the topic selection page; instead of having an "objects" path and "KS3 topics" path, we combined the two paths into one single home page which is shown in screenshot 7 shown below in the table. This page simply categorizes the 4 different gallery maps that we had in Prototype 1, so the "object" gallery map in Prototype 1 was simply changed into "All Topics" Gallery map, which is shown in screenshot 11. The other three gallery maps remained the same in terms of naming it. The new version of the gallery maps can be seen in screenshots 8, 9 and 10.

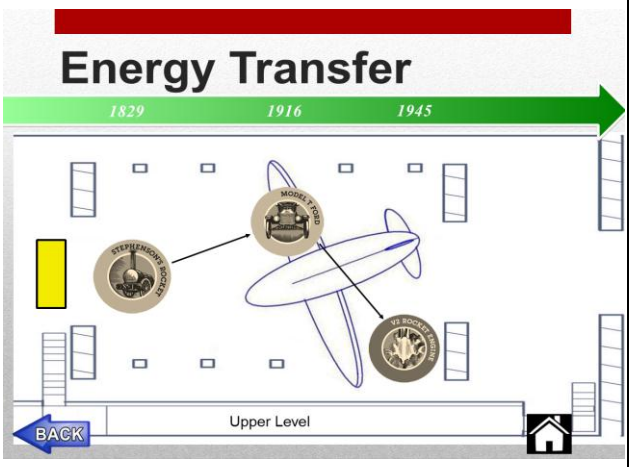
7) Topic Selection Page



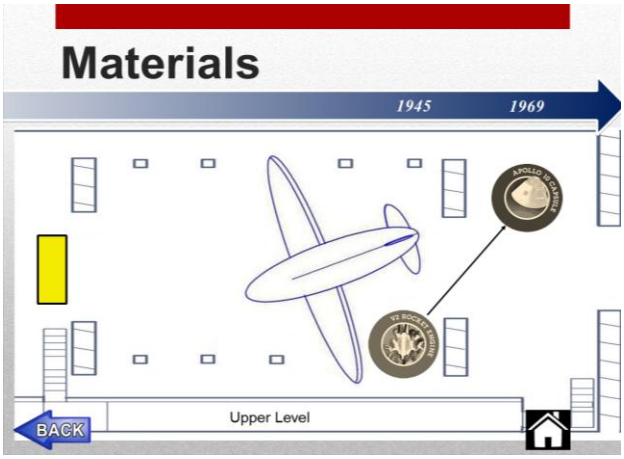
8) "Forces" Gallery Map



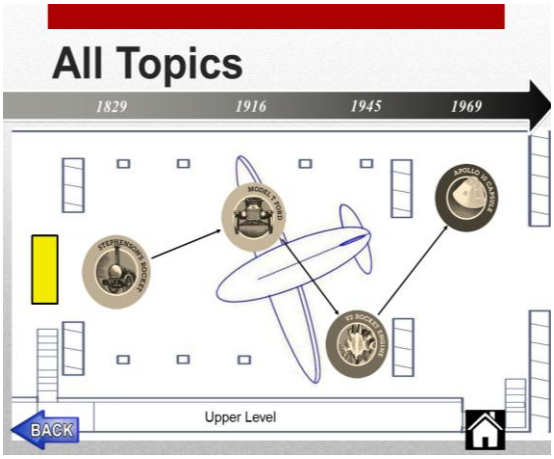
9) "Energy Transfer" Gallery Map



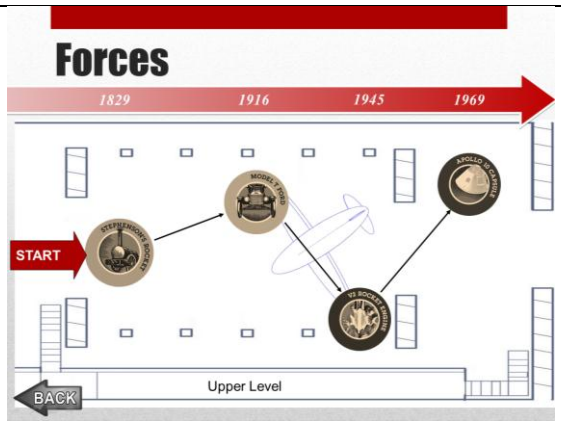
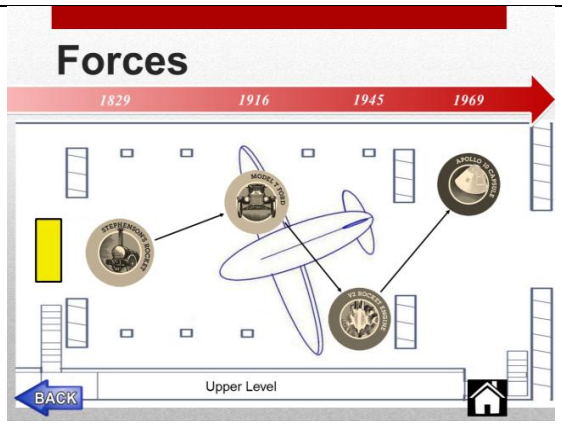
10) "Materials" Gallery Map



11) "All Topics" Gallery Map



In terms of the gallery map content, no major design changes was implied to the gallery maps in Prototype 2. In the table below, the "Forces" gallery map is taken as an example to show the design changes done to the gallery map.

Prototype 1	Prototype 2
	

As seen in the table above, the following changes were implied to all four of the gallery maps in Prototype 2:

- The size and orientation of the airplane in the map has changed as to better represent the object's actual location in relation with the airplane.
- A yellow rectangle was added at the entrance of the *Making the Modern World* gallery as to represent the yellow description panel located there in the gallery map which is explained in the tutorial. This was added as another point of reference for teachers to orientate themselves in the gallery.
- Home button was added so it would bring the user to the "Topics Selection Page," and the back button now simply brings you back to the previous page you were at.
- Style of title text is changed.
- Color of back button is changed.

Appendix M: Prototype 2 Testing Aims & Objectives

Testing: 7 KS3 Science Teachers

Focusing on:

- Content
- Engagement
- Usability

Aim
Does the target audience find the app's content useful and engaging?

Objectives

- Can the teacher imagine themselves using the application with students in the museum?
    - Could they share the object information? Is there enough information?
    - Could they share the visual aids?
    - Could they use the activities?
    - Could they start discussions using the given questions?
- Does the teacher feel the students would be interested in the app's content?
- Is the app's content relevant to the KS3 science curriculum? (i.e., materials, forces, energy transfer)
    - Would the content be *suitable* for the students?
    - Does it cater to a range of ages and abilities of KS3 students?
- Does the teacher find it helpful to have activities and questions arranged in order of increasing difficulty?
- Does the teacher find the app helpful?
    - In terms of logistics?
    - In terms of making a more engaging learning experience in the museum?
- Would it be beneficial for the teacher to have the app beforehand?
    - Would they prefer to have the information before arriving at the museum or just before using it with students?
    - How would they like the content to be delivered to them?
- How easily can the teachers navigate the app?
    - Have the changes made in the design improved the functionality of the application?
    - What are some issues in usability that are still regularly occurring?

Appendix N: Prototype 2 Testing Questions and Observation Sheet

Preamble

- We are developing a new application for teachers to use while in the *Making the Modern World* gallery with their students
- Very preliminary stage, still in the beginning stages of development
- No right or wrong way to use this app
- This is a Keynote presentation – there are no iPad touch screen capabilities (i.e., no pinching, double clicking)
- We are not testing you as a teacher, we're just looking at the functionality of the app itself
- Please don't hesitate to give us your most honest and critical answers – we won't be offended!
- Please feel free to talk out loud as you use the app so we can get a better idea of what you're thinking
- We will be writing down what you tell us and what we observe, but it will be confidential. The data collected from this visit will only be used anonymously in our report.
- We will start with preliminary questions, followed by an accompanied visit through the gallery. Here you will be able to freely use the app for a while before we ask you some questions. We will end with more questions at the end, which may take a little longer.

Pre Questions

1. Have you brought a school group (i.e., KS3) to the Science Museum before?

   Y / N

2. (If yes to #1) Did you prepare any educational materials prior to visiting the Science Museum with students? (i.e., pre visit or post-visit activities)

   Y / N

   a. Probe: (If yes) do you feel this helped you while in the museum with your students?

3. Would you be interested in using a mobile guide for a tour in a museum?

   Y / N

   □ Prompt: Would you use a mobile application as a guide while in the museum, say on a mobile phone or iPad?

   □ Probe: What makes you say that?

Observations

Interview Questions

- Can you imagine yourself using this [activity, discussion point, visual aid] with your students?
    - Probe: Can you tell me in what sort of ways?
- Would you be confident enough to reiterate this to your students without reading it previously?
- How would you use that activity/question?
- Do you prefer one of these [activities, questions, visuals] over the others?

Things to look out for

- Clicking where there's no link
- Clicking without reading text
- Facial expressions/body language
- Do they read the text fully before moving on?
- Did they skim the page or read/play it fully?
- Initial reaction
- Does it look like they're making connections between the iPad and the object? (Glancing back and forth)
- Did they read the object labels?
- Are they distracted?
- Did they skip or avoid one section?

Tutorial

- Did they read, skim, or skip the tutorial pages?
- If you were on a school visit do you think you would want this information before entering the gallery?

Home Page

- Do they understand the "all" option? What do they think that button would bring them to?

Gallery Maps

- Could they orientate themselves within the gallery?

Stephenson's Rocket

Object info

Visual Aids

Activities

Discussion Q's

Model T Ford

Object info

Visual Aids

Activities

Discussion Q's

V2 Rocket Object info Visual Aids Activities Discussion Q's
Apollo Capsule Object info Visual Aids Activities Discussion Q's
OTHER

Exit Questions

1. What is your overall impression of the app?

2. What did you like about this app?

3. What did you dislike about this app?

4. Would you find the app helpful?

   Y / N

   - ☐ Probe: In terms of logistics?

     Y / N

   - ☐ Probe: In terms of engaging students?

     Y / N

5. Did you understand the options on the Home Page?
   - ☐ Probe: Did you know what each button would take you to? Y / N

6. What do you think you would gain from using the app? How could it help you?

7. Is there anything that really confused you?

   Y / N

   - ☐ Probe: (If yes) which aspects?

8. Other than the tutorial, would you find it helpful to have app in advance?

   Y / N

   - ☐ Probe: Would this help with planning your museum visit?

     Y / N

   - ☐ Probe: Would it help you to better understand the function of this app?

     Y / N

   - ☐ Probe: Would you prefer to have the app's information before arriving at the museum or just before using it with students?

9. How would you prefer to have this information given to you?

- □ Probe: Would you prefer to get it via email or the Science Museum website?

- □ Probe: Would you like the information in the form of a Microsoft Word Document, video, PowerPoint, etc.?

10. Do you think the app caters to a range of KS3 students?
Y / N

- □ Probe: Would the content be suitable for different ages?
Y / N

- □ Probe: Would the content be suitable for different students' abilities?
Y / N

11. Do you think the forces content is relevant to the KS3 curriculum?
Y / N

- □ Probe: What about the energy transfer content?
Y / N

- □ Probe: The materials content?
Y / N

12. Would you find it easy to share the object information with your students?
Y / N

- □ Probe: The visual aids?
Y / N

- □ Probe: The activities?
Y / N

- □ Probe: The discussion questions?
Y / N

13. Do you think your students would enjoy:
The object information? Y / N

□Probe: Why is that?

The activities? Y / N

□Probe: Why is that?

The discussions? Y / N

□ Probe: Why is that?

The visual aids? Y / N

□ Probe: Why is that?

14. Do you prefer visual aids, discussions, activities, or object information?
    - □ Probe: What makes you say that?

15. Would you find it helpful to have activities and questions arranged in order of increasing difficulty?

    Y / N

16. How would you use each section with your students?
    - □ Probe: Would you prefer to use one section over the other?

17. Is there anything that might prevent you from using this resource with your students?

    Y / N

    - □ Probe: Why is that?

18. Did you find the gallery map helpful? Y / N

19. Did you find the tutorial page helpful?

    Y / N

    - □ Probe: Did you read all of the information on it?

      Y / N

    - □ Do you think you would read it while on a museum trip?

      Y / N

20. Is this app something you can see yourself using in the classroom?

    Y / N

    - □ Probe: Do you think it's more suitable for a museum setting? Y / N

21. Is there anything specific you feel we can do to improve this prototype?

Appendix O: Prototype 2 Pre-Question Spreadsheet

Sheet Number	Date	Observer	M/F	Age Bracket 1=16-18 2=19-25 3=26-35 4=36-50 5=50+	Brought school goup to Science Museum before?	Prepare and educational materials prior?	Did this help?	Interested in using a mobile guide for a tour?	Would you use a mobile app as a guide on somehting like amobile phone or iPad?
					Q1	Q2	Q2a	Q3	Q3a
1	6/10/2012	DM & JL	M	2	N (other museums)	N/A	N/A	Yes (definitely)	Phone might be more accessible, more flexible and less "risky"
2	6/10/2012	LS & BZ	F	2	No (English Teacher)	N/A	N/A	Yes	Yes
3	6/11/2012	LS & BZ	F	2	No (Not as a teacher, only as a chaperone)	N/A	N/A	Yes. It would be quite helpful, help us them	Yes
4	6/15/2012	LS & BZ	F	3	Y	No	N/A	Y	yes, other wise its just letting the students run loose. They just love the lanuch pad and go there and skip everything else
5	6/15/2012	LS	M	3	N	N/A	N/A	Y	Y
6	6/15/2012	DM & LS	F	2	Y	No	N/A	Y	Y - makes it more
7	6/15/2012	DM & BZ	F	2	N	N/A	N/A	Y	Y - we use phones for everything these days so why not?

Appendix P: Prototype 2 Post-Question Spreadsheet[8]

Questions 1 – 4

Sheet Number	Date	Observer	M/F	Bracket 1=16-18 2=19-25 3=26-35	Overall impression	Likes	Dislikes	Would you find this app helpful?
					Q1	Q2	Q3	Q4
1	6/10/2012	DM & JL	M	2	It's a step in the right direction, it's important to improve interactivity w/historical objects. Students say they're able to just wander on museum trips, this app would change that	He knows about some of the objects' history, but this app taught him more about them	The Home button should take him back to the main Home Page (like his Home button on the internet will always take him Home). There should be another button to take him to the Home Page (understood the process after it was explained). There should be worksheets based on the app's info (this will guarantee the teacher will use the app). Questions & activities should be leveled more specifically than easy-> hard (3-4, 5-6, etc.)Groups of students are varied! Questions would be even more valuable back in the classroom.	Yes (walking around with it gives him more info to teach)
2	6/10/2012	LS & BZ	F	2	Very clear and easy to use. Fun for teachers and students. Contains in depth exploration of topics at the same time.	Easy to use. Touch screen is fantastic. Back, Home, and Map buttons were clear. Discussion questions were interesting, funny and well thought out.	Nothing really. Map at first because it was confusing at first, it needs to be labeled better but got much better once she got used to it.	Yes, definetly.
3	6/11/2012	LS & BZ	F	2	Its really good, activities right now through are more for TOP END KS 5-6 students. They are good but not so easy for the kids.	Likes the pictures a lot. You could get different teachers/chaperones with smaller groups and show them to the small groups individually. This makes organization very easy	Don't like that you can't go back straight away with the [BACK] button. Needs more activities like "go and find this" kind of activities, this will help the kids going and requires less thinking. Many students are lacking the literacy, so they need something easy such as just gathering information rather than striaght analyzation.	Yes, definetly.
4	6/15/2012	LS & BZ	F	3	Likes the idea - it gives more informatin to teachers, it will engage students with a few tweaks. For example , with added animations of a working engine would be really cool.	Actually rather easy to use as soon as she gets used to it. Information was quite clear, pictures were quite helpful - some could be bigger, for example pictures of parts of the rocket.	She found she had to go through a lot of things to know what was there. She would like an overview page that shows her what brings her to what, and where she would given to her in the links of the app.	yes
5	6/15/2012	LS	M	3	Really impressed. Clear, easy to navigate, lots of good information, well presented.	Activities, facts, it's relevant to topics. Layout: organized, colors used. It's really clear.	Map and navigation were confusing. Would like to have something like a GPS tracker so you could always tell where you were in the gallery.	Yes, absolutely. The iPad really adds to the process
6	6/15/2012	DM & LS	F	2	liked it - something she hasn't seen before. Makes the trip more interactive w/out bringing in materials from home	clear, smooth, easy to use. Looks interesting, attractive. Flows nicely	force diagram on Model T is unclear (a lot going on) -> maybe have one force show up at a time or label them all	Y - helps to have it with you (have a quick glance, read aloud) even if you're not familiar with it's information
7	6/15/2012	DM & B	F	2	quite clear, very visual, nice colors. Well laid out, different sub-topics. Easy to understand buttons (gallery vs. home)	clear basic info (started everything), activities & discussion q's (laid out easy to hard - could target different students), map (once she got her bearings it was very straightforward). Allof it - very cool!	there should be a list of which objects fall under each topic so you could cover more at each object without walking back and forth	Y - definitely. Students will run around w/out focus otherwise. She teaches science but wouldn't know a lot about the objects. This app focuses on different aspects of ea. object and gives ideas for activities and questions

[8] The color coding is as follows: (at the top) Engagement, Content, and Usability; (in the spreadsheet) Positive, Neutral, and Negative.

Questions 4a – 7a

In terms of logistics?	In terms of student engagement?	Did you understand the options on the home page?	What do you think you would gain from using the app? How could it help you?	Is there anything that confused you?	Which aspects? (if yes)
Q4a	Q4b	Q5	Q6	Q7	Q7a
N/A	Yes (definitely - the more info he knows, the more engaged the students will be)	Yes (Knew what each button would take him to. If he was organizing a trip, he would do it with the topics in mind and might come specifically to cover one topic (came for a reason!). App targets curriculum as much as possible	It would enrich the museum experience. More valuable learning would take place and there would be less wandering.	Yes	Home button
Yes, definetly.	Yes, very much.	Yes, however recommends to put ALL on top.	Could structure a series of topic lessons from this. Could take it back to classroom to expand upon OR work up to it (IF they had the iPad before then could plan classes up to museum visit)	Yes	The map at the beginning. The topics was confusing as well.
Yes, IF she could see the app before. Or have a little dot that says: "You are here."	Yes, it makes them feel special, they like that personal connection. Making it relavent to them, sometimes they can't see directly the connection so we need to tease the information out.	Yes!	Orgaization and time first most. Then next it would help behavior management, because it just takes out the extra stress less to make the teacher's job easier.	No	Just a little bit disorientating of the map at first. And the [back] button at first.
yes, would help instead of just walking through the gallery, with the activities it would be harder to track them because you would send them off.	Yes, but not for my students	Yes, didn't understand all at first - where it would take her	Gives her more information, could use the the dicussion questions and activities.	Yes	Just "ALL" option
Y	Yes, the activities are really stimulating, especially the go and find activities, and there's a good range.	Yes: very straightforward	The activities would stimulate students. There's information that you wouldn't otherwise have access to. The students can interact with teacher and information.	N: all really clear	N: all really clear
Y	Y	Y	helps students with questions through open ended activities, helps to see where objects/curriculum are related. Opens up questions and starts discussions	N - she started at Puffing Billy though, which confused her initially	See Q7
depends on size of group	Y - variety of activities and questions but some get repetitive (i.e., forces q's and activities) - but you don't have to do all of them	Y	getting extra info she can relay to students, being able to focus students on what they need to look at. Each activity is related to object and is straightforward - gets students involved	Y	what to do with the map in the tutorial (understood later). Sometimes she confused the back button w/the home button but then later understood the back button literally goes back to the last page you were at

Questions 8 – 9a

Helpful to have in advance?	Would this help planning?	Would it help better understand the function of this app?	App information prior to arrival or before use with students?	How would you prefer to have this information given to you?	Email or Website?
Q8	Q8a	Q8b	Q8c	Q9	Q9a
Yes. It's really important to have it in advance. Teachers look at the ScM website before trips anyway for resources. This gives structure for students (especially if they don't go to museums often on their own & don't understand how to learn in them). He would still use the app in the museum though. Students would be more inquisitive if a teacher is holding an iPad - wonder what's on it.	Yes (would give him confidence & give the visit structure)	Yes	Before arrival	Ideally, the education section of the ScM website, but via email would be fine. Any access in general would be helpful.	Website
Yes, she would find the whole thing more helpful, not just the tutorial.	Yes	Yes. It not just make it easier, but makes the teacher more comfortable with using it because it is easy to be flustered in front of so many	Before arriving or as early as possible. So that teachers can also plan classes BEFORE	If downloadedable, that would be best. Others are find too.	via Email
Yes, she would like the whole thing, so she could look at which activities are suitable for whom.	Yes	Yes. Because of the layout, couple of hours or night before would be best.	Couple of days, depends on how the teacher would plan it though.	A link sent to them via email would be best. Such as a webpage or code for the app and teachers could download it themselves via the web onto their ipads or phones.	The website, so the teachers are sent a link of the app that is located on the ScM website and teachers are just sent the weblink via email and just nee to click and download off the ScM website.
Yes, it is essential. They cannot do it without preparation. Some pages have too much information, kids expect teachers to be knowledgeable of everything while they are not so preparation is really important.	Yes	Yes	information befroe arriving at the museum so they could choose what to use.	email or email them a direct link to the app on the website	ideally the whole app would be best. But next would be a word document.
Y, it would be useful to have it sent out via email so teachers could look through it.	Yes: what questions to use and what to focus on	Y	Before arriving, probably about a week before	Email or emailed link to ScM website	Ideally email because some teachers might not be familiar with apps
Y - it's be nice, but not always necessary. The app is very easy to use, wouldn't need it in advance all the time	Y - would add more activities/materials to trip she wouldn't have thought of	N/A	N/A	would go to look for it on the ScM website if she knew about it, but emailed would be preferred b/c it's easier	email
Y - really useful. Tutorial was short & clear but having it advance would save her even more time	Y - could get more info on objects & learn more about them	Y - app is great but takes practice, then it's easy to use	before arrival	N/A	email (it's easiest)

Questions 9b – 11a

Word Doc, video, PPT, other	Does the app cater to a range of KS 3 students?	Would the content be suitible for different ages?	Different abilities?	Forces content relevant?
Q9b	Q10	Q10a	Q10b	Q11a
PPT. The app is simple enough, wouldn't need to be put in a video. PPT would be easiest	Some. There needs to be more for diff. levels for every section (q's, activities, etc.). The ebst way to do this would be to have KS3 teachers sit down & come up with activities, worksheets, etc.	N/A	To a degree, but not enough	Would become valuable after trip (referring to Model T visuals). Visuals are helpful & worth having, but would be more valuable in classroom. Good to have on worksheets & teacher would have answer on iPad - the info is more helpful to students, teachers should already know it. Could show the visuals to a couple of students, but they'd want to take the iPad - better for teachers to have than students.
These would be fine but would prefer whole app	Yes, definetly.	Yes	Yes. It covers enough simple ground, and then also has enough for the higher leveled as well.	GUESSES YES. (enlgish taecher)
"App all the way!" in cleass activity, the teacher actually did an activity with the students with draw something and they totally loved it. Students really like seeing the relavence of using teachnology and such. Seeing an adult use it will help them.	No, caters to more a higher end of students.	Yes, but not all of them.	No, much higher end. The lower end need more questions where they just look and discover information rather than thinking activities or mind processing activities.	Yes. Loves the arrows on the force diagram.
Word doc	Yes, you could use it at the KS3 and KS4 but would work better with KS3 higher levels kids.	Yes	Yes	Yes, some would share, some wouldn't. For example the stephenson's rockets pictures are actualy quite tricky to show because it isn't very clear right away.
Ppt	Yes, but it ight be helpful to put in curriculum links separated by years and topics based on what students study in each year.	Y	Y	Yes
Word Doc or PPT (couldn't print out video if she wanted to)	Y - some q's a bit difficult (i.e., forces) but there's nice differentiation and open ended q's	Y - even lower aged KS4 (15-16yrs) or lower KS3 (10-12yrs)	Y	Y - just taught forces, space is very interesting to them
video or powerpoint (most useful)	Y - b/c of differentation in q's and range of activities (ex. Year 9 may be interested in calculations while year 7 might like role playing activities)	Y	Y	Y - relevant, contains key words they need to learn, ties in nicely (i.e., forcec diagrams)

Questions 11b – 12c

Energy content relevant? Q11b	Materials content relevant? Q11c	Easy to share object info? Q12a	Easy to share visual aids? Q12b	Easy to share activities? Q12c
It would be helpful to have the pic's info on the zoomed in pic itself. What's going on inside the object is what's interesting. Useful to learn about the fuel inside V2 - didn't know that. The info is useful. Combustion in Model T is good - pics need to be labeled more clearly if given to students. Likes the Compare & Contrast Q about technology. Visual aids are good, but it would be better to have them connected to activity	Yes, but not a lot of materials science in KS3 curriculum. Apollo's content is more KS2	Yes - for a well behaved group	Some of them - really liked V2 visuals, but Stephenson's energy trasnfer is a little confusing	Yes - but more differentiation is needed
GUESSES YES. (enlgish taecher)	GUESSES YES. (enlgish taecher)	Yes, definetly.	Yes. Again, there should be a booklet/handout for the students. This way, the learning is more.	Yes. Great, but some would be better to do in class instead of here in the museum floor.
Yes. Likes it, they usually find it difficult to be relavent.	No, its more for the higher end of the students. Its more for the end of KS3 with the atoms structure and such. With the plastic material, her students might need a little more to be able to handle that material.	Yes. Definetly, but only in small groups, 6 max per group.	Yes, rocket helps with seeing things more.	Yes. More finding activities rather than discussion and thinking activities. Stephenson's rocket's activity: would this model work? It's a really good question that makes them think.
Yes, depends on what KS3 students, many tend to struggle with that.	Yes, that is fine.	Yes	Some of them, want more links to more material	Yes. Easy to do, but some can't be done in the museum because of many people and the limited space in there. Also the noise level will effect it.
Yes	Yes	Yes	Yes	Yes: model answers are helpful because it tells teachers what to look for
Depends on year in KS3 (better for the older ones)	Y - relevant to all ages	Y	depends on size of group	Y (perfect)
Y - all the stuff they cover originally in year 7 (revisited in year 9), definitely relelvant to curriculum	Y - properties of metals in year 8/9, periodic table - all of it is good	Y	Y - straightforward in small groups, and she could pass around the iPad in larger groups (or go around to students)	Y - straightforward, but they may need pencils & paper for some of them

Questions 12d – 14

Easy to share questions?	Would students enjoy object info? Y?	Would students enjoy visual aids? Y?	Would students enjoy activities? Y?	Would students enjoy questions? Y?	Did you prefer object info, vis aids, acts, or q's?
Q12d	Q13a	Q13b	Q13c	Q13d	Q14
Yes - some are excellent. Good, open ended questions, but he would lose half of the students' interest if the material wasn't right in front of them	Some would be more interested than others	The large pictures need to be labeled - holding the iPad up w/out labels wouldn't work as well	Some would. It is better than having no activities at all.	N/A	Discussion questions. Object information is good to have as a teacher
Yes. Great, but don't want to rush them so the longer questions she might prefer to do in the classroom to gain more in it due to time constraints.	Yes, definetly.	Yes. Definetly, that's why they would want a handout or booklet. To share this information.	Yes, definetly. They are ethical, challenging, dynamic and interesting.	Yes.	All good. No favorite.
Yes. Really likes them. Needs a morequiet area however to conduct them. "My lot doesn't shut up." - she likes the idea of sending her troops out to gather information and just report back to her their discoveries.	Yes. Making personal connections make it relavent and more important for them.	LOVED THEM. Pictures were really helpful.	Yes, Higher end students would find it really interesting. However, the lower end would just find it boring.	This could be quite heated. She has quite strong opinioned students so this would be a great section for her students.	I don't know, she quite likes all of it. The space capsule is her favorite though however its only for higher level KS3 students.
Yes, they are fine.	Yes	yes, but there is a limited screen size	Yes, if she chose the appropriate ones.	Yes.	Dicussions.
Yes	Yes	Yes, but wishes they were more interactive (i.e., click to reveal facts or animated images)	Yes, especially liked the compare and contrast activities	Yes because they're interesting and relevant to curriculum	Activities because they're reallyl stimulating, relevant to topics. They can generate really good thinking for students. The "go and find" activities really encourage independence.
Y (nice)	Y - links to something they can think about, stuff they're interested in	problem is letting them all see it	Y - most of them, but might not use them after a while	Y - definitely, especially for higher level students - good b/c she spends a lot of time with lower level students so the higher ones will have some attention	discussions, activities - different ideas she wouldn't normally think of, allows her to familiarize herself w/the museum
Y - could have them work in pairs or discuss together	Y - they would be interested (info isn't too word-y, student friendly language)	Y - colorful, clear. Easy to understand (not too complicated), therefore they'll be engaged. Concise, looks accessible	depends on students/age (higher level will like calculations, lower level will like kinesthetic activities)	Y - higher ability would enjoy them more, but everyone would overall - interesting to discuss, real life context, accessible	visual aids - shows science theories in a nut shell

Questions 15 – 18

Would you find it helpful to have activities and questions arranged in order of increasing difficulty?	How would you use each section with your students?	Anything to prevent you from using app?	Gallery map helpful?
Q15	Q16	Q17	Q18
Yes. Differentiate everything! Have specific levels. Helpful for before and after visit	Ask them lots of questions about the object, might give the good students the iPad to read object info out loud. Have them look at object for a while, then come back and do activities. Would do the same thing with misbehaving students, but less would be interested.	No - it's a source of info for him. It would help him engage students more than if he didn't have the app, but it would help more if it was more interactive. Could make them feel more independent if they were given their own tablets/worksheets	Yes - doesn't know the SciM very well, but most science teachers would know it better. Most people wouldn't get lost like he did. It's made as best as it could be! The plane helped to orient himself
Yes. She did see that and found it very helpful.	Read out each section's information to students. They are all good.	No	Once she got used to it, it was fine.
Yes, definetly.	No preference of one section over antoher, if she came, she couldn't do all the section. She would do only specific setions. If you had it before, you could use worksheets to work before to send them off. She likes worksheets in the museum, that supports them doing it. Leaving a physical memory and labour helps.	No. She likes it. Just its very higher level. Loved the pictures where she could probably make her own questions and activities.	Yes. It's a little bit disorientated at first. But good after she got used to it.
Yes, definetly. They weren't that easy however. (Apollo ones were all quite hard, the enviormental q's were actually easier than rated because it doesn't require too much knowledge and people nowadays know more and more abou environmental	Read/ give them the object information. May or may not show them the visuals aids. Defiently do dicussion questions but not all of them. Would take a look at the activities, but in most cases probably won't do all of them. She might make a worksheet based on the activities and questions.	No	Yes.
Yes	Start at front of the gallery, working their way through in a linear fashion. Start with easier questions and activities and work their way up.	No	No: needs work. Could be more interactive, incorporate navigation system.
Y - good for mixed ability groups	prefers object info & activities over visual aids (likely to use more often), but the visuals would be fine w/a small group	No	Y
Y - really good. If she came w/ "bottom set", she'd know not to use harder questions	read info out loud to them, have them read object panel, enlarge pictures to show them. Go through viusals, read tasks for activities and set them up (same with questions). Prefers discussion questions - helpful	No	Y

Questions 19 – 21

Tutorial page helpful?	Read all the information?	Would you read it on a museum trip?	Is this app you would use in a classroom?	More museum suitable?	Improvements?
Q19	Q19a	Q19b	Q20	Q20a	Q21
Yes - but the app was self explainatory anyway (besides the home button - it changes depending on which page you're at)	No	Probably, but he would want to see it before the visit - more likely to read if he was given the PPT before. Kids could help teachers with the app if they needed it	Yes	Yes - more activities (differentiated) would be helpful	There should be animations instead of static images - he would definitely show these to students (i.e., combustion images, force arrows changing size). This would be a more valuable learning tool - replace most of the pictures with animations. Students would be able to see them easily, only depends on their behavior. Force diagrams should be more scientifically accurate.
Yes	Yes	No, would need to prepare beforehand.	Yes, definetly.	Museum because the objects are here!	No - Just the ALL category on the toipcs page like she alerady said should be the first option. Incorporation of other objects would be great but understands that there is time contraint on teacher's half. Other than that, ITS EXCELLENT!
Yes, it just a standard tutorial in any app that one doesn't know how to use.	Yes	Yes	No	Yes! Its always helpful in museum floor. Its really better on museum floor, would be difficult to do in the classroom rather.	More dingin/discover/ "get this info" kind of activities. And add a "you are here" dot on map to help orientation.
No, she knows how to use iPad so its really easy	Yes, she followed all the small directions such as zoom in and touch the activities.	No	No	Yes	Having some sort of overall structure introduction before starting or given the app, so she knows what is offered in each section.
Yes	Yes	No, but hopefully would have seen it beforehand	Yes, having access to activities at your fingertips is brilliant	Yes	Improved navigation, side bar to navigate from topic to topic without having to go to the home page.
Y - straightforward	Y	Y (if she had time at the start)	Y - transferable - could use after trip to follow up with what they saw	N/A	more kid friendly language (specifically for her school where English is a second language)
Y	Most of it - skimmed	No	useful for teaching in classroom, but would be less interactive	Yes	list which objects correspond to each topic, larger range of activities