Project Number:

A MUSEUM WITHOUT WALLS: A DIGITAL TOOL FOR THE ROYAL ARMOURIES

An Interactive Qualifying Project Report
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by

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1. computers
2. archive
3. accessibility

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Abstract

This report, prepared for the Royal Armouries Education Center located at Her Majesty's Tower of London, describes the creation of three tools to assist archiving and exhibiting of information contained in the White Tower. The tools include a digital archive, a virtual tour, and a virtual Line of Kings exhibit. This project responds to the Royal Armouries' staff's requests for an updated archive and an increase in accessibility by providing better-maintained exhibit records and online access to the White Tower.

Table of Contents

Table of Figures

Authorship Page

Members of our team contributed equal effort to the overall project. However, each member performed different tasks in each area of the project. For simplicity, we describe our project tasks in two categories: work, and composition of this report.

We divided work into two further categories, research (including social and background) and development (thematic and technical). We performed our social research by conducting interviews, and observational research. Shaun and Sarah conducted off-site interviews, while all members of our team were involved in those performed at the Tower of London. We performed visitor observations in the White Tower: Ben conducted ant trails, Shaun characterized visitors, and Sarah observed attendance variations. Mike filled the role of primary technical developer, although Ben also assisted directly in the development of the tool.

We composed this report and other written materials by assigning primary content creation of individual sections to different members of our team, and then editing the results. Sarah was the primary content composer for the introduction section, and Ben filled a secondary role for that section. Sarah gathered background information on the Tower of London, while Ben assembled information on the societal importance of museums. Shaun created the technology in museums section, which Sarah supplemented. Mike was the primary author of the Software Engineering portion, to which Ben later added. Our entire team contributed to each of the subsections of both the methodology and results sections. Shaun, Sarah, and Ben generated the discussion and conclusions sections, and Shaun created the initial recommendations section. Editing of the paper was ultimately a group effort; however, Ben took on a primary editorial role throughout.

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We thank all the individuals who took time to meet for interviews that provided vital information for our report. These include Andrea Gilbert, Roy Stephenson, Chic Mackie, Henry Roberts, and Elizabeth Sands.

Finally, we would like to thank our advisors Professor Petrucelli and Professor Brattin for their aid and encouragement throughout our project.

Executive Summary

Currently there is no complete visual archive of the previous or current displays at the White Tower. Museum planners require records of past exhibit layouts and designs to create better exhibits in the future; the White Tower is entering a five-year redisplay period, and will benefit greatly from a digital visual archive. In addition, areas of the White Tower are inaccessible to disabled individuals, but the Internet can allow some individuals to experience this content. Finally, members of the Royal Armouries' staff speculated that interactive technology can improve the educational value of some of the exhibits in the White Tower, such as the Line of Kings.

We created the framework for a three-part digital tool to solve the problems detailed above. First, we created a visual archival tool for the Royal Armouries' staff. Next, we extended the archival tool to form the basis for a publicly available virtual tour of the White Tower. Finally, we gathered photographic resources and created an on-paper layout of an educational and promotional virtual program to represent the Line of Kings exhibit. We identified firsthand the importance of exhibit layout and visitor flow by conducting observational research in the White Tower, including attendance variation observations, ant trails, and visitor characterizations. Our team also conducted interviews with staff members at the Tower of London, as well as staff members at other museums, to identify requirements and directions for our tool. We also used Software Engineering practices and tools, such as iterative development, during the creation of the digital portion of our project's product.

Our methodology produced two forms of results: the data we collected from observational research, and the three aspects of the tool. The observational data provided visitor flow and profile information intended for inclusion in the visual representations found in the archival aspect of our tool, and the tool provides a functional framework for digital archiving and virtual display of the museum. Analysis of these results revealed visitor flow problems in part of the White Tower, and justifies the use of our tool to help amend them. Evaluation of the tool showed that it is user-friendly, takes advantage of appropriate visual and textual elements in an easily navigated interface, and provides dynamic control over representations of the museum.

We concluded that our project addressed the issues of accessibility and education in museums. Royal Armouries' staff at the Tower of London may use the archival tool to identify and represent problem areas in the White Tower, in turn leading to redisplays of exhibits that may improve visitor flow and content accessibility for the majority of the visitors to the Tower of London. The virtual tour is available on the Internet, which provides worldwide accessibility of its content and contributes to the museum's goal of educating the public. The virtual Line of Kings exhibit tool extends the educational purpose by providing an interactive formal learning environment. The tool also represents the staff's hopes for the exhibit's future appearance, which should assist in the acquisition of sponsorship for a redisplay.

We also arrived at a series of recommendations concerning improvement of the White Tower's accessibility and extension of our tool. We reiterate visitor flow suggestions originally obtained from interviews with White Tower warders, and support these suggestions with our observational data. We also supply recommendations for additions to all three aspects of our tool so that subsequent developers can easily continue to improve the services the White Tower provides.

1. Introduction

Informal learning is a form of education that allows individuals who are motivated by their own interest in a subject area to explore information independently. Museums are centers for informal learning that provide visitors with clear and accessible information, and aim to enhance the visitor experience, increase visitation, and encourage education. To accomplish these goals, museums strive to create well-planned environments, and they look to innovative changes in exhibit design and educational programming such as planned events, demonstrations, and outreach programs to improve the learning experience. Generally, increased interactivity between visitors and exhibits improves the effectiveness of informal learning. Museums now utilize digital technologies such as internet services, including virtual tours and visit planners, in addition to other computer- and entertainment-based programs, to engage visitors and appeal to other audiences.

The Royal Armouries' staff at Her Majesty's Tower of London is responding to modern trends by conducting research on the White Tower's visitor flow and information accessibility. The staff aims to improve visitor education and experience with this information. We contributed to this goal by conducting observational research, and developing a digital tool that allows the staff to visualize visitor flow data. In addition, our tool provides a dynamic digital method of photographically archiving the exhibits at the White Tower. The Royal Armouries organization maintains a vast collection of arms and armor, a fraction of which is at the White Tower. Although the organization carefully selects display layouts from their collection, there are no accurate catalogs of prior exhibits at the White Tower, which the staff may use to incorporate previous successful exhibit ideas. Our research and the corresponding tool will allow the staff at the Tower of London to record the current layout of exhibits at the White Tower, provide the framework for a public virtual representation of the museum, increase the accessibility of the exhibits, and create a sample virtual educational exhibit of the Line of Kings display.

The design and implementation of the tool involved an interview process that utilized iterative development (a cyclical process involving inclusion of user feedback

during the implementation process). We evaluated the impact of the tool firsthand by observing the staff's use of it, and the impact that it has on visitor experience.

2. Background

This section summarizes the important findings from our research on the Tower of London, its history and current use, the significance of museums in social and cultural contexts, and the use of digital technologies in museums and planning.

2.1 Her Majesty's Tower of London

As one of the most historic structures on the north bank of the Thames, the Tower of London attracts more than two million international visitors each year (Waterfield, 2004). The Tower of London is one of the many important sites the Historical Royal Palaces (HRP) organization supervises. HRP conserves historical sites and palaces in the United Kingdom for Her Majesty, the Queen of England. The White Tower is the central keep of the Tower of London, and its displays of arms and armor are from the Royal Armouries' collection. The Royal Armouries (RA) also maintains collections of arms and armor at various locations outside of London including Leeds and Fort Nelson in the United Kingdom as well as Louisville, Kentucky, in the United States of America.

2.1.1 History of the Tower of London

The Tower of London has stood as an important structure in London, England since its initial construction in 1078. William the Conqueror sailed from Normandy to seize his cousin's kingdom, and he was crowned King of England on Christmas Day, 1066. His first act as king ordered the construction of a castle that would amaze English citizens and provide protection for his administration (Hibbert, 1971, 14-18). The Tower of London features slit windows, three rectangular turrets, one rounded turret, and flat walls for maximum protection. Over the years, caretakers made improvements including whitewashing the central tower to make it appear enormous among the wooden houses of the city, hence its name White Tower (Hibbert, 1971, 20).

In 1091, William Rufus, William the Conqueror's son, repaired and strengthened the Tower of London. Further construction took place during the reigns of Henry III and

Edward I, and included the addition of bastions, gateways, towers, and protective walls. The location of the castle and its additions made the Tower of London one of the largest and strongest fortresses in Europe, as seen in Figure 1 (Hibbert, 1971, 20).

Figure 1 – The White Tower: A strong fortress built in 1078.

Although the Tower of London served the Crown well, in 1529 King Henry VIII's main residence became Whitehall Palace, at which point the Tower of London became a state prison. At other times in history, the White Tower was as a treasury, a mint, an arsenal, and a home to the Crown Jewels. It is currently a world-renowned museum of arms and armor.

2.1.2 The Tower of London Today

Despite having over two million visitors each year, the Tower of London remains in good condition and is one of four World Heritage Sites in London (Hughes, 2004, 112). Visitors can observe the Medieval Great Hall and the Chapel of St. John on the entrance and first floors of the White Tower, respectively (see Figure 2). By climbing to the second floor, visitors can view the temporary displays in the West Room (Historic Royal Palaces, n.d.).

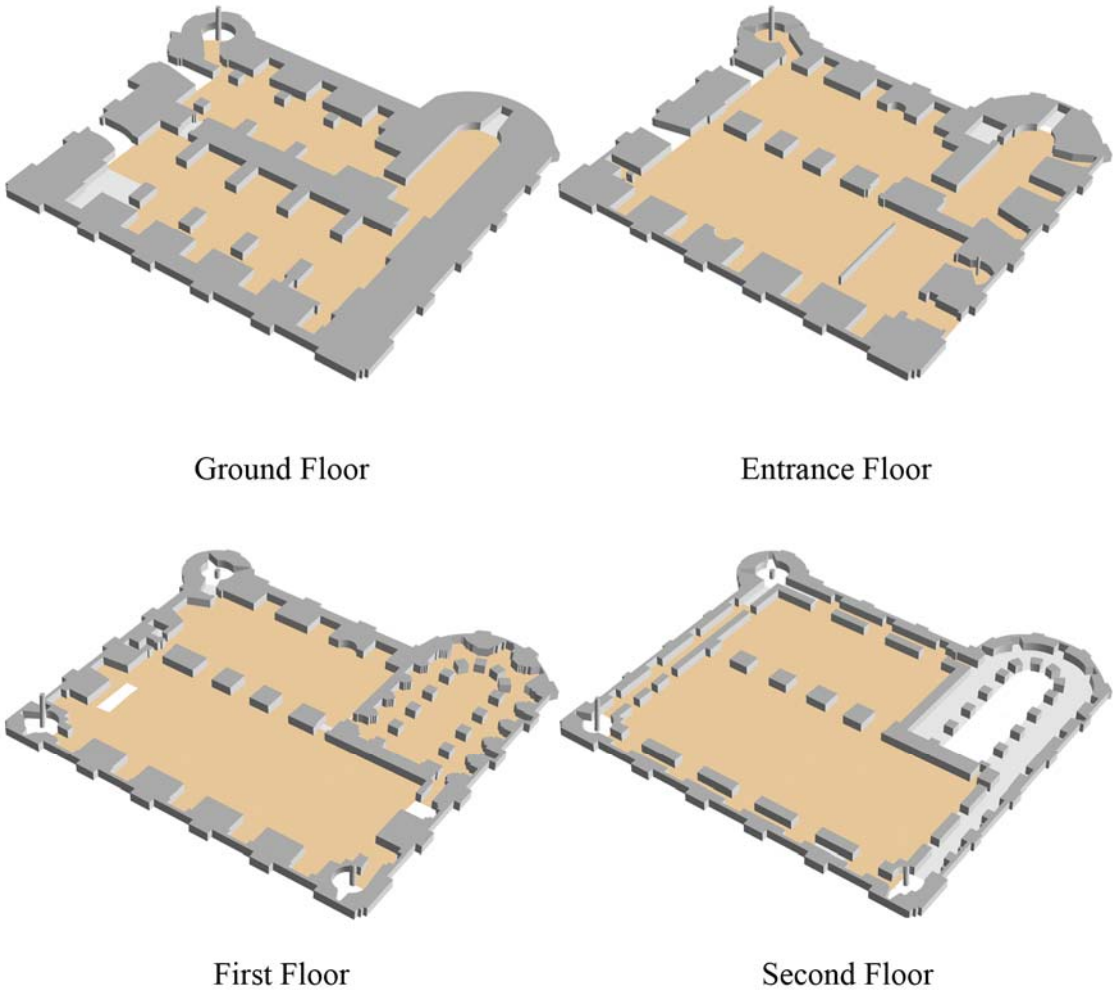

Figure 2 - Floor plans of the ground, entrance, first, and second floors of the White Tower.

The Tower of London has become the repository for an impressive collection of historic or otherwise important artifacts collected since 1565, including armor, weaponry, and jewels. Every year people travel from around the world to see the Crown Jewels displayed at the Jewel House, including the Black Prince's Ruby and the Koh-i-noor Diamond. Other marvels include the large collection of arms and armor at the White Tower, a fine example of which is the armor of Tokugawa Ieyasu, Shogun of Japan, given as a gift in 1613 to King James I of England. The Royal Armouries' displays the armor of King Edward III's son, John of Gaunt, at the White Tower and the armor measures 2.057 meters. The decorative armor of Richard, Duke of York to the side of the John of Gaunt display stands 0.952 meters. In addition, several armors in the Royal Armouries' collection belonged to King Henry VIII, King Charles I, and various other

figureheads. Visitors consider exhibits in the White Tower—such as the Line of Kings display created in 1660 to acknowledge the restoration of the English monarch—to be historical marvels themselves due to the amount of time they endured. The Royal Armouries' staff at the Tower of London maintains the displays of arms and armor, and will be redisplaying the museum in the White Tower over the next five year.

2.2 Societal and Cultural Importance of Museums

Museums serve as the keepers and presenters of knowledge, allowing the public to experience information and objects that would otherwise be reserved for academics and the elite in society. Falk and Dierking (2000) write that museums "are places that both children and adults can leisurely browse to discover the past, present, and future of humanity, the natural world, and the cosmos, where the public can seek and find meaning and connection." These authors emphasize that "as America and the rest of the world transition from an industrial to a knowledge-based economy, knowledge and meaning-making more than ever before become key to social and economic well being" (1–2). People often visit museums due to their leisurely environment, attention to meaning, entertainment, social and life events, and even recreational activity. Most importantly, museum visitors learn from these experiences (72). Consequently, we can expect that museums will play increasingly important roles in the future.

2.2.1 Learning in Museums

Duncan Cameron distinguishes between museums as "temples" and museums as "open forums." Museums that serve as temples have a "timeless and universal function, the use of a structured sample of reality, not just as a reference but as an objective model against which to compare individual perceptions." Those museums that serve as forums are open to "confrontation, experimentation, and debate" (as cited in Karp and Lavine, 1991, 3). Karp and Lavine (1991) concluded that modern museums are trying to serve as forums, although at the time of their writing, many displays failed to reflect this goal (3–4). Increasingly, however, museums are pushing toward this goal, and are beginning to support more interactive displays.

While Karp and Lavine focus on establishing the formal function of museums as learning centers, Falk and Dierking (2000) take greater interest in the nature of the learning itself, claiming that learning is a very complex process that encompasses more than just presentation and absorption. They believe that "it is better to think more holistically, to think about learning as a series of related and overlapping processes," and thus they develop a "Contextual Model" of learning (in museums) that comprises personal, socio-cultural, and physical contexts (9–10). In the personal context, the authors explain that emotional and motivational prompts drive learning, which personal interests support by constructing of knowledge from previous experience. Important to museums, however, is the contextual aspect of this learning; it occurs in a specific context that museums provide (15–32). The physical context is the result of the interplay between "behavior settings"—readily visible in children interacting on a playground—and "situated cognition," or the "need to make sense of the environment" (54–65). Although their model explains each of these contexts in detail, the socio-cultural aspect is of particular interest to our project, as the goal is to improve the museum experience. The authors identify cultural conditioning (the process by which individuals adopt similar mindsets as other members of their society) as a cause of meaning-making, stating that children and adults alike form these notions through learning processes such as modeling (imitation). Falk and Dierking conclude that learning through imitation is common within museums (39–50) and that "central to all learning is our perceptual system" (17). Therefore, the art of display and arrangement of museum exhibitions facilitates learning.

2.2.2 Impact of Interactivity on Education

Education depends greatly on interactivity in social (interaction with teachers or peers) and physical situations (technology, environment or other non-human interaction) (Ambe-Uva, 2005, 4). McManus claims the social interaction in museums and education centers is the foundation of the educational experience (as cited in Wellington, 1990, 248). Education centers allow learners to explore new information through their personal interest and self-motivation. Wellington (1990, 250) suggests that:

> …'hands-on' science centres contribute to the cognitive domain in two ways: directly, by providing new knowledge *that* certain things happen in certain circumstances; and indirectly, by sowing seeds and leaving memories which may ultimately lead to understanding.

Although Wellington gives less praise to education centers for 'cognitive' education, he does claim they contribute immensely to the motivation of visitors and awareness of learning. These social and physical interactions create a connection between the learner and the educational aid (i.e. a teacher, a computer, a peer), which often leads to the learner's educational success (Ambe-Uva, 2005, 4).

Recently many formal education centers, such as schools and museums, have incorporated interactive methods to complete curriculum more effectively. Education centers commonly use computer programs with quick response times, continual interactivity, and receptive and adaptable capabilities. Computers allow users to enter wide collections of ideas into a program, and consequently the programs enhance and expand learning as more users view the information (Mikovec and Dake, 1995, 124). Online courses serve as an example of the use of technology as an interactive medium to aid education. In 2000, the National Center for Educational Statistics reported that 89 to 90 percent of the public two-year and four-year institutes in the United States offered online education courses. Furthermore, studies showed high levels of student interactivity during the courses, and timely feedback from professors resulted in positive attitudes of students and high success rates in the course (Durrington, 2006, 190). Therefore, online technology improves education by providing extended accessibility to increase education.

2.2.3 Exhibitions

Belcher (1991) claims that humankind has learned to be "exhibition-conscious" of appearances and relations of objects in the world, and has collected and exhibited objects since antiquity. The museum, as a venue for exhibitions, contains within it a representation of culture and society. The exhibits in a museum, regardless of their content, are a form of art because of their design and display, which affects the viewer in an emotional way (37–41). As Belcher states, "[b]ringing object and viewer close together is the most important function of museum exhibitions" (38), but the means for doing this are very much up for debate. Karp cites a variety of assumptions made during the organization of exhibits, including "the judgments of the aesthetic merit or authenticity of the objects or settings used." These assumptions lead to a common difference of opinion concerning the general model of an exhibition, those models that

are “a vehicle for the display of objects” and those models that are “a space for telling a story.” Karp concludes that regardless of the specific model of the exhibits, the “aesthetic response” to them builds from viewers’ previous external experiences (as cited in Karp & Lavine, 1991, 12-13). Falk and Dierking (2000), who state, “The entire world of educational experience, the educational infrastructure, contributes to and reinforces learning from museums,” also acknowledge the importance of this experience (113).

Indeed, the informational, societal, and cultural value conveyed by an exhibition lies in the interactions between the viewers and exhibits. Museums continually change to accommodate expectations and new forms of interaction. The varieties of “modes of exhibitions,” such as permanent, temporary, and traveling, exemplify these changes. Other accommodations relate to “types of exhibitions” which include “emotive,” or affecting; “didactic,” that is, instructional or informative; and “entertaining” (Belcher, 44–57). More recently, museum staffs have begun to utilize digital computer based exhibits and museum-planning tools to improve each of these types of exhibitions, as well as museums in general.

2.2.4 Museum Layout and Design

Any exhibition—or any other form of display or interaction—in a museum benefits greatly from careful planning and design. The physical context of an object may be of more importance than the object on display, since various influences external to the object itself affect viewer perception. To elicit effective learning, the viewer of an object must have some interest in it. Similarly, a museum must inspire interest in its displays. Falk and Dierking (2000) relate the level of viewer interest to the levels of ‘curiosity’ and ‘novelty.’ “Curiosity evolved in order to facilitate learning, learning occurs in order to satisfy curiosity,” and novelty is “how we describe unfamiliar environments, events, or objects; curiosity is how we respond to them” (Falk and Dierking, 2000, 115). The authors assert that the best environments for learning bring out high levels of curiosity, but only moderate amounts of novelty (Falk and Dierking, 2000, 115).

The authors also provide a set of methods to achieve higher levels of learning, including preemptive measures (such as an “advance organizer” that reinforces expectations of spaces and objects), and design choices in the displays themselves

(organizing information around displays in a manner that accommodates the average mental processing power of a visitor). The authors understand that museum learning occurs best when there are not too many sources of information, and cite studies in which they show that objects nearer to the entrance of any given museum receive more attention. The authors indicate that other studies have shown that non-linear displays (those displays that do not present their information like a series of chapters, but rather as natural clusters) enhance learning. The use of grouping is extensible on many levels, from elements of an individual exhibit, to placement of similar exhibits in the museum space (118–122). Falk and Dierking also elaborate on the use of design principles to enhance the visitor experience. They indicate the importance of the overall layout of the museums in terms of object placement and the impact of space on the visitor's eyes and feet for informal learning. In addition, they claim the use of shape and mass (e.g., a pyramid implying stability or instability based on its size and orientation), and color, texture, and pattern affects the visitor's apprehension of exhibits (123–126).

2.3 Trends in Integrating Technology in Museums

Given the ever-increasing effectiveness of technology in the fields of planning, design, and interactive media, museums find that using technical resources greatly improves the visitor experience and positively affects learning. This section details museum staffs' efforts in integrating many forms of technology to help enhance learning through wayfinding, virtual museums, and accessibility, and explores computer programs of importance to our project.

2.3.1 Wayfinding

Wayfinding is a systematic method by which visitors are able to navigate through a space. Successful wayfinding presents users with an easily followed, clearly communicated pathway. Museums employ wayfinding in such a way that knowledgeable staff may suggest several planned pathways to provide customers with sufficient choices to ensure personal satisfaction. Museums use a variety of tools as supplements to wayfinding, such as maps, landmarks, signage, and kiosks. The purpose of these tools is to provide the visitor with direction, information, and identification of objects

(Mclaughlin, 2005). Providing the museum visitors with tools that lessen disorientation and stress will improve visitor flow and visitor experience (Durrington, 2006, 190).

Museum staff and visitors plan pathways through museums, and wayfinding tools must provide information to indicate direction and availability of exhibits for both groups. Important aspects of wayfinding include visibility, flexibility, value of information, location, and reliability. Wayfinding tools must include adaptable features to integrate the museum's needs, since modern museums have become dynamic institutions. They must also be easily accessible to the public and provide clear, useful information, allowing visitors to navigate to "a destination that fulfills his larger purpose" (Foltz, 2005). Visitors choose pathways based on their evaluation of the information at hand, such as present route, previous routes, intersections, and information they seek to learn. Successful pathways support visitor satisfaction, and informational assistance enhances pathway choices. Therefore, successful pathways and informational assistance increase the success of wayfinding, as well as visitor experience.

Memorable locations, such as landmarks, help visitors familiarize themselves with the space of a museum. Foltz (2005) describes landmarks as "the anchors along which paths are defined and our mental maps are built; they [landmarks] should reflect the top level of the organizing principle of the space" in order to maintain minimal confusion among visitors. Landmarks, informational kiosks and signage assist in navigating. In museum settings, particularly the Tower of London where many visitors travel great distances, patrons may only visit a museum once. Due to the limited number of visits, it is important for visual effects, such as coloration, to be eye-catching and to place handicap accessories, landmarks, and signage with various languages, appropriately in the designated area (Kellman, 2006).

Wayfinding tools include paper and digital maps, as well as mobile electronic devices, such as personal data assistants. As visitors' objectives may change due to environmental, physical, or technical changes, it is necessary to create adaptable wayfinding tools. The interface of the tool should also be user-friendly in order to be effective (Li, 2006). Navigation tools must provide the user with clear instructions, certainty in routes, and a limited number of choices to decrease environmental stress.

Staffs at many museums have begun to transform their displays from a 'no touch' educational experience to a hands-on interactive learning environment. The Tower of London staff aspires to connect history with modern society by integrating interactive elements in museum design.

2.3.2 Virtual Museums

Museums now make use of digital applications to increase accessibility of museum information. Shiode and Kanoshima (1999) discuss the effectiveness of using cyberspace to create a virtual environment for a museum visitor (79). The virtual museum allows a user to examine the museum's exhibits from an environment in which they may be more comfortable, such as their own home. The Internet provides users with virtual access to museums' collections, as well as reference databases. The Internet creates a bridge among countries and allows museums to form connections more easily. These connections include relationships among museums, countries, schools, universities, and individuals from all areas of the world.

Shiode and Kanoshima (1999) define the idea of a "virtual museum" as an electronic reproduction of a museum that contains artifacts for public viewing, and has the same spatial feel as an actual museum (1). Virtual museums allow individuals to traverse a visual representation of the museum without having to leave their home. They act as a portal for users who may not have physical access to the museum, such as disabled users. Virtual museums also serve as wayfinding tools, permitting users to plan, which in turn focuses and expedites their visits.

2.3.3 Accessibility

Many historically significant sites, such as the White Tower, are physically inaccessible to many individuals because site caretakers are unable to convert the structure of the building in order to make it more physically accessible. The caretakers must also consider individuals unable to visit for reasons other than a physical disability. Therefore, the site's staff must utilize other methods to provide these individuals with access to the information within the location. Many staffs turn to the Internet to reach these individuals. Virtual museums and online databases provide individuals with access

to content while maintaining the visitor experience. However, the Internet has its own set of accessibility issues.

Wakefield (2006), of the Georgia Institute of Technology's accessibility website, states that, "Accessibility - in the context of content presentation on the Web - refers to the ability of an individual to utilize online content even when functioning under limited conditions." The World Wide Web Consortium (WWWC) published a guideline for creating accessible websites called the Web Content Accessibility Guidelines 1.0 (WCAG) (Chisholm, Vanderheiden, and Jacobs, 1999). These guidelines outline the general layout and design of websites in order to maximize accessibility. Observing these guidelines makes the finished product accessible to a wider range of audiences.

Even when following the guidelines, there is no way to produce a website that is accessible to everyone, because a fundamental matter such as language can cause accessibility issues. A fully accessible website needs to accommodate nearly 800 languages (Bryne, 2005). Developers find it difficult to create a website that accommodates so many languages, and many tend to develop websites for limited audiences instead.

Andrew Pae outlines a few simple steps to make a website accessible to a larger audience in his article "Some simple techniques in making your website accessible." Providing images, graphs, tables, and multimedia with descriptive text allows individuals who are vision-impaired to understand the contents of a picture by using a program that audibly reads the caption. Content and formatting options, such as short and direct sentences with large fonts, can also help many individuals (Pae, 2007).

Some computer programs automatically assess and improve a webpage's accessibility. The Java Accessibility Application Programming Interface (API) creates alternative versions of Java Applets for individuals with disabilities (http://java.sun.com, 2007). Bobby, another accessibility assistance program, looks through a website to determine if it follows WWWC accessibility guidelines (http://webxact.watchfire.com/, 2007).

Accessibility has become a major issue in current society, and more developers are creating planning tools geared toward enhancing accessibility.

2.3.4 Programs

Many commercial computer programs are able to create floor plans and assist in redesigning building layouts. Some programs bear similarities to parts of our tool, even though the intent of most is for architectural design. One such program is SmartDraw, which Carnegie Museum of Art in Pittsburgh recently chose for gallery layout, network diagramming, and other drawings. SmartDraw contains more than 60,000 design templates, shapes, and symbols to facilitate the creation of floor plans. SmartDraw is very versatile because it can function on any scale, from inserting objects of any size into an exhibit, to planning entire museums (http://www.smartdraw.com, 2007).

There are also many programs created to assist in the archiving of materials and the creation of databases, such as Bamboo. This program can archive various aspects of objects, such as text, audio, video, and photographs, and it allows for easy entry of data through a file/folder system complemented with simple commenting and description creation features (http://dev.riseup.net/bamboo/, 2007).

On the commercial market, numerous programs are able to produce a virtual tour, ranging from a pictorial walkthrough to a complete virtual reality tour. A program similar to our project is Mapwing by Redbug Technologies. It is a virtual tour creation program made for Macintosh computers which allows the user to input a map, add pictures of objects taken from different perspectives, and create a visual walkthrough. It is user-friendly and affordable, and is a valuable model for our program design (http://www.mapwing.com/, 2007).

More advanced products include three-dimensional representations, such as Virtual Reality Development Lab by Digital Tech Frontier L.L.C., a package that allows a user to create a virtual reality environment in which an individual can experience moving through a full three-dimensional atmosphere. Virtual reality environments create active learning experiences, by aiming for full user immersion. To be effective, these environments usually require advanced (and expensive) technology, such as headsets and even motion sensing control interfaces (http://www.wecantakeyouthere.com, 2007).

Our tool contains elements of digital archiving, exhibit planning and analysis, with strong connections to public education. To enhance each of these aspects we examined the programs above, in addition to other resources.

2.4 Software Engineering Practices

Software Engineering is the application of engineering principles found in Computer Science and other professions to the structured development of a computer application. There are typically three steps involved in any Software Engineering project: analysis of components, description of key features, and designing a developmental flow chart.

When developing any software the first elements to consider and analyze are the different components of the project. Such components include what operating system and hardware devices the program is to run on, as well as the type of interactions it will have with its users. Such information creates initial boundaries for the software, allowing programmers to design the software within them. Developers assign priorities to their project goals following an analysis of the key features of the program. This step clearly explains what the customer's specifications are, helping programmers create an effective program. The most important idea in Software Engineering, however, is versatility, as the customers can adjust or request additional specifications at any time during the development process (Steinberg, 6-10).

It is essential for a Software Engineering team to create a flow diagram for their production, even though it is subject to constant change. There are many different ways to design a project flow chart; one of the more common methods results from the Spiral Model.

2.4.1 The Spiral Model

Developed by Barry Boehm in 1985, the Spiral Model minimizes various risks and problems found in Software Engineering, such as time management problems and cost overflows. This model continuously assesses every part of the development of the project, minimizing the risk of having an incomplete or flawed program. The cycle begins with the establishment of initial requirements, followed by a design stage, implementation, and finally with testing. The cycle repeats, taking into account new user requirements that may have developed over the previous iteration. An illustration of this model is in Figure 3, below:

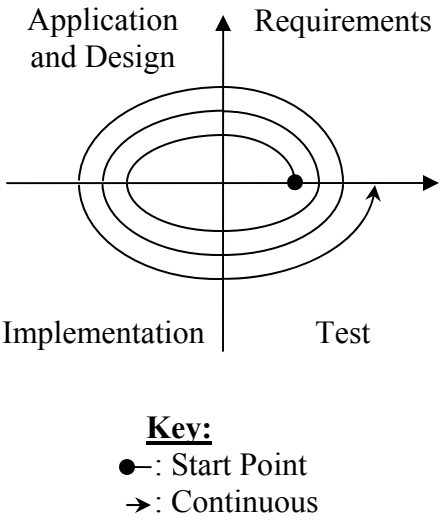

Figure 3 - Barry Boehm's Spiral Model.

The spiral model minimizes the risk of having an incomplete or poorly working program at the end of the project. It is worth noting that designers using the spiral model are far more likely to meet deadlines than designers who use more linear methods (Steinberg, 12-13).

2.4.2 User Stories and Use Cases

The first two stages of the development cycle described by the Spiral Model, Requirements and Application and Design, are integral to the production of a program that meets user requirements and expectations, but it is often difficult to obtain the necessary data for these steps from users who lack the technical background necessary to describe them adequately in programmable terms. Use cases and user stories can provide a bridge between clients and users who are concerned with end-product features and programmers who need to understand those features in the form of easily programmed tasks.

Writing use cases is a technique for capturing functional requirements of systems. Each use case provides one or more scenarios that convey how users, also called actors, should interact with the system to achieve a specific goal or function. Use cases commonly do not include technical details, and are in the preferred language of the user. Use cases allow the user to understand what the programmer believes the program is to do, and suggest changes so the project proceeds in the correct direction.

To help convey the flow of a system, use cases commonly include flow charts or diagrams to help demonstrate the interaction between user and system. As most systems have multiple interaction paths, a use case commonly includes alternate flows. In addition, use cases include specific prior and post conditions to a scenario. An example of a use case is in Appendix B**.** Programmers employ use cases to demonstrate to the customer what the general interactions with a system are, and for every action in a use case there is a user story.

User stories are small, specific interactions that the user expects to have with the system. Users write user stories after receiving some specific topics of interest from developers. The resulting stories provide unbiased indications of what a user expects to see and do within the program, and, if the user chooses the proper topics, provide very specific indications of the tasks the development team needs to undertake. User stories can help illuminate important or priority features and issues, and they can be collected from multiple users to obtain general client preferences. Subsequent iteration can clarify any ambiguities in the stories, after implementation or added to future use cases.

Use cases and user stories can also help developers overcome one of the drawbacks of the Spiral Model, namely the difficulty in creating a project timeline. By estimating the length of time it will take to implement specific user stories, developers can create timelines for completion of more general use cases, and forecast a general outlook on the progress of a project. Use of these methods also helps the client and specific users of the program to prioritize features so those programmers spend time implementing the most important ones. Unlike requirements documents, use cases and user stories avoid references to specific technology, databases, and algorithms as much as possible. They focus on user needs, while providing defined tasks and directions to programmers, who may then decide which programming language and tools they need to meet these requirements.

2.4.3 Application Development in Java

Java is hardware independent, making any tool created with it usable on a variety of computers, and code written in the language is easily transferable to web-based systems. Java is also very developer-friendly; its support for Object Oriented

Programming allows programmers to develop understandable, reusable code in a structured manner. There is a very large community of Java developers, as well as a detailed and comprehensive support base provided by Sun Microsystems, the creator and maintainer of the Java language. A wide variety of resources are available to the Java developer, including a wealth of literature in both print and digital form, interactive tutorials, classes, and other educational media. Therefore, development of many tools and applications support or work in conjunction with Java.

2.4.4 Applications Supporting Java Code Development

Other applications further enhance the effectiveness of the Java language, including SourceForge and Eclipse. SourceForge is a web-based system for organizing and distributing workload to team members of a project, and features forums, private messaging, and mailing lists to enhance communication among team members. Projects developed on SourceForge are Open Source, making their code accessible to the public, and more importantly, other developers. Developers can utilize a file release system provided by the site to post downloads of their software, making distribution to specific clients and the general public much easier. SourceForge also provides a "Compile Farm"—hosts running different Operating Systems on which developers can test their software. Most importantly for our project, the site maintains a version control system (repository) that records and backs up every submission of code to a project. The Concurrent Versions System (CVS) supported by SourceForge allowed the members of our team to collaborate on various parts of the project safely (i.e. without worrying about overwriting or deleting important files or code). Development applications, such as Eclipse, support easy access to the CVS system.

The Eclipse Platform is a programming environment built for use with Java. It supports a customizable display of code style and project layout, and provides a direct method of submission (commitment) of code to version control systems, such as the CVS featured on SourceForge. Individual project updates uploaded easily to the repository through Eclipse. An interactive editor brings up project files that bear the same name and displays differences between the files, allowing developers to make sure their submissions do not overwrite important code or files. Eclipse also supports many plug-ins, such as code analyzers and requirement trackers, to assist code developers.

3. Methodology

This section details our methodology for completion of our project. We focused on furthering our understanding of additional background, social, and technical resources, as well as research techniques. We utilized these techniques to varying degrees to supplement the construction of different aspects of our tool. Appendix C provides a timeline detailing the specific tasks we performed. In addition, a flow chart visualization of our methodological tasks is in Appendix D.

3.1 Techniques

The background and social research and technical development we completed were essential aspects of our project. Research we collected from various sources not only aided us in the development of guidelines for our tool, but also ensured that the final product met expectations. Although each of these research techniques is unique, we used them in conjunction to construct the final product.

3.1.1 Background Research

We used additional background research whenever possible, especially to acquire documented information. Sources included books, files, and photographs available at the Tower of London. The Royal Armouries' staff suggested many of these, and we continued examining other resources we located through our own supplementary background research. We acquired additional information via the Internet, such as electronic final reports of previous Worcester Polytechnic Institute projects—especially, but not limited to, those performed at the Tower of London—and other online resources, such as museum association web sites.

3.1.2 Social Research

We utilized social research methods during the implementation and evaluation phases of the development of our tool to gain information relative to its design and requirements, as well as its impact. To gather this information, we conducted interviews involving members of staffs at the Tower of London and other museums, and

international students. In addition, we recorded data about museum visitors using observational techniques.

3.1.2.1 Interviews

We conducted structured and semi-structured interviews with the members of the staff at the Tower of London and other museums. Each type of interview involved an interviewer and note taker. We examined notes for accuracy immediately following the interview, and we clarified ambiguities in the notes with subsequent follow-up contact with the subject. We used a list of carefully selected questions to ask staff members during structured interviews, while we used a list of topics for semi-structured interviews.

Members of the Tower of London's staff were the subjects of interviews that served to increase our team's understanding of the goals of the museum, including the specific goals that the museum staff has for its use of our tool. Interaction with our liaison directed us to other individuals to interview at the Tower of London and other museums. Subsequent interviews focused on additional needs of the Tower of London staff.

By interviewing staff at other museums in London, we gathered information on other archival methods and suggestions for improved archival tools. Examination of these tools provided high-level direction for our development of our own, and showed that other developers implemented many features similar to our own. We also examined other student-developers' progress on similar tools during their production, and we compared our production process to theirs to reevaluate our direction.

International students studying in London evaluated the virtual tour tool after interacting with the tool. The students provided us with feedback on the quality of our user-friendly aspects through semi-structured interviews. We inquired about navigation, layout clarity, and contextual feedback. The students represented four different countries including France, Japan, America, and Malaysia (see Appendix E).

3.1.2.2 Visitor Characterization Observations

As a supplement to our program development, we conducted a number of observations to create a visitor profile. A visitor profile is a summary of the total visitors broken down into specific categories. Our visitor profile included information on the

number of males and females we observed entering the Line of Kings exhibit. In addition to these observations, we noted the approximate age of each individual. The purpose of these observations was to influence the Royal Armouries' planned redisplay of the White Tower by providing a synopsis of the audiences who traverse the White Tower on a daily basis.

One member of our team performed these observations from the entrance to the Line of Kings exhibit. From this vantage point, we counted the number of visitors entering the archway, and determined if each was alone or in a group. We also approximated the age group visitors belonged to by categorizing visitors into three age ranges: less than 30 years of age, 30 to 60 years of age, and 60 years of age or more.

We conducted these visitor observations over a period of five days at different hours during the day. We inputted the data collected from these days into Microsoft Excel to produce the graphs located in our results section. These graphs contain the information that outlines the visitor profile we observed. We examined this data to identify common themes and to summarize the results for the Royal Armouries' staff to consider.

3.1.2.3 Attendance Variation Observations

Unobtrusive observational research, in which researches do not inhibit the visitors, allows for natural and accurate data collection. We evaluated the visitor number fluctuations in the White Tower by recording visitor numbers every two minutes in a discrete manner at the Line of Kings exhibit, and we noted that school groups greatly increased visitor numbers. We gathered data on various days throughout the week including Monday, Thursday, and Friday. We also conducted research on a Sunday during a United Kingdom school holiday to evaluate the increase in visitor numbers, which, according to members of the staff at the Tower of London, resemble summer visitor numbers. After graphing and analyzing the data, we provided the Royal Armouries with information about visitor number fluctuations that may contribute to visitors' experiences in the White Tower.

3.1.2.4 Ant Trails

We conducted our ant trail observations on the entrance floor of the White Tower. During an observation period, one member of our team followed an individual or group of visitors through the entrance floor and documented what exhibits visitors viewed, in what order the exhibits were viewed, how much time the group spent at each exhibit, and whether members of the group read labels (partially or in full). The observer also took notes on various other events, such as whether members of the group took pictures of exhibits, and whether any interaction between a member of the group and the exhibit took place. In addition, the observer made every attempt to remain unnoticed by the group he or she followed; the observer documented visitors from a distance and did not interact with the subjects. Our team entered the resulting data into Microsoft Excel for organization and analysis, and made a sample flow image that we intended for the archival tool.

3.1.2.5 Evaluation Feedback

Evaluating the effectiveness and usefulness of our tool was important to ensure the final product met the goals and demands of the staff of the Royal Armouries. One of our goals was to provide a digital archiving tool to maintain records of exhibit layouts. This tool needed to be user-friendly—especially to the Royal Armouries' staff—and effective at helping the staff recognize areas of congestion within the museum. The Royal Armouries' staff plans to use this tool as a foundation for their five-year museum redisplay plan.

We gathered evaluation feedback during our final weeks in London through user interviews. We evaluated the accessibility of our online virtual display by surveying international students, and we conducted interviews with staff members to gauge their comfort and satisfaction with the tool.

We analyzed and integrated the resulting data from interviews and research into both our tool and final project report.

3.1.3 Technical Development

We conducted the development of our tool in conjunction with the techniques described above and in our timeline (see Appendix C). To enhance the effectiveness of initial interviews of the staff at the Tower of London, we built a prototype interface of our tool. Then, during the iterative cycle, the tool underwent constant redevelopment based on information found in our research and, in particular, feedback from the Tower of London staff. Finally, during the evaluation phase of our development, we recorded and implemented smaller alterations to the tool as needed, and we developed plans for possible future development of the tool. To develop this software efficiently and correctly, we followed standard models of computer application design, administered structured interviews to gain pointed insight into user goals, and used development tools and applications that encouraged communication, organization, code security, and quality.

We followed the Software Engineering practices discussed above in conjunction with Java and associated development tools also described in our background, as well as Adobe Photoshop for image editing. We decided to adopt a less formal method to bridge the gap between user expectations and technical program requirements. To gather information similar to that provided by use cases (see section 2.4.2), we used informal and semiformal interviews with key members of the Tower of London staff (see Appendix F), and we observed the staff using versions of our tool to provide the specific information that the staff would have generated from user stories.

3.2 Application of Techniques

The background and social research directly influenced the development of our final digital tool and established a set of evaluation criterion for the tool. The tool has three main applications, which function as standalone programs. These applications include a digital archival tool for the Royal Armouries' staff, a virtual tour for the public, and the framework for an exhibit-visualization tool designed to aid in the development of the Line of Kings exhibit. The three applications are interrelated; we constructed the virtual tour as a polished extension of the archive tool, allowing access to interactive virtual exhibits.

3.2.1 Archival Tool

Documentation of the displays in the White Tower has been incomplete since the White Tower opened as a public museum. The staff members at the Tower of London requested that this project include a digital archiving tool to assist the staff in analyzing exhibit documentation to improve future exhibits. Our tool combines digital photographs of displays, information about the artifacts and their museum labels, as well as areas of congestion and spatial deficiencies within the White Tower in an interactive virtual display. We included these aspects to provide the staff with the necessary information to create clearer and more interactive exhibits in the future, ultimately enhancing informal learning.

Our tool consists of an overall Tower of London map, which links specifically to the White Tower through buttons placed on specific map locations. A display of the exhibit layout depicts the visitor flow and artifact information by floor. Users are able to input information on the artifacts through text boxes, and can show the areas of high and low congestion through a data tab.

Our team created the program by entering data collected from research into the Java computer language, which worked with the Eclipse software to create a user-friendly and adaptable program. The tool is user-friendly for staff members, and allows entry of more data on the White Tower's collections as they change in the upcoming years. Our team made the program adaptable, as it will be the foundation for the virtual tour, which the staff will complete in the future years.

3.2.2 Virtual Tour

The staff at the White Tower requested that we modify our digital archiving tool so it can serve as a virtual tour available to the public via the Internet. This allows individuals unable to visit the Tower of London to experience its exhibits.

This part of our tool is a restricted, view-only version of the archival tool that does not include visitor flow information, but features information from the White Tower that is valuable for learning. The program follows the Royal Armouries' new branding guidelines for formatting elements such as color and font. Our tool allows importing of

exhibit and artifact information from the archival tool for future updates to the online portion.

We incorporated information gained from additional interviews with Tower of London staff, and our research helped us understand thematic and technical requirements for our development.

3.2.3 Line of Kings

The Line of Kings exhibit is an incomplete display depicting some of the past kings of England. When the White Tower staff first unveiled the Line of Kings exhibit, it contained over 18 kings in their armor on horseback. Currently, the number of kings has diminished to only ten, the armor is no longer on horseback, and the majority of the armor is now placeholder armor. The decline in the quality of this exhibit stemmed from display mistakes and lack of funding.

There were historical inaccuracies in the Line of Kings exhibit since its original development. After numerous attempts to recreate the exhibit and correct its historical inaccuracies, the exhibit moved from display to storage. In 1998, the Royal Armouries' staff brought the kings' horses out of storage, planning to reassemble the exhibit. Since then questions have arisen as to whether or not the staff can recreate the exhibit.

The intent of the new exhibit was to display ten kings in their armors on horseback. Some of the original—and inaccurate—armors are currently at other museums and storage locations. This problem, and the inability of the old wooden horses to carry the weight of armor, has led to the decision to recreate the armors using fiberglass. The price of this endeavor could be staggering and will require commercial sponsorship.

We developed a framework for an educational representation of the Line of Kings that will also help raise money, as it provides potential sponsors with a clear image of what the display can potentially look like. Although our initial rendition of the exhibit is two-dimensional, the staff may expand it into a three-dimensional education.

4. Results

The application of our methodology produced results in two categories: data from social research, and our digital tool.

4.1 Social Research

We used four social research techniques to gather data pertinent to our project and our tool. We used ant trail observations to identify areas of the entrance floor of the White Tower that had poor visitor flow, as well as to estimate how well visitors use labels. We also categorized visitors by age, group, and gender to understand the different audiences to which the Royal Armouries' exhibits appeal. In addition, we observed visitation to the Line of Kings exhibit in two-minute intervals over multiple hours on different days. Finally, we compiled results from interviews we conducted to guide the development of our tool.

4.1.1 Ant Trails

Our ant trail observations provided our first indication of the problem areas for visitor flow in the entrance floor of the White Tower. Visitors spent much more time at some exhibits than others; as seen in Figure 4 below, the Decorative Columns, Line of Kings, John of Gaunt, and Trophies of the Spanish Armada exhibits each experienced twice the average visitor attention than most other exhibits on the floor.

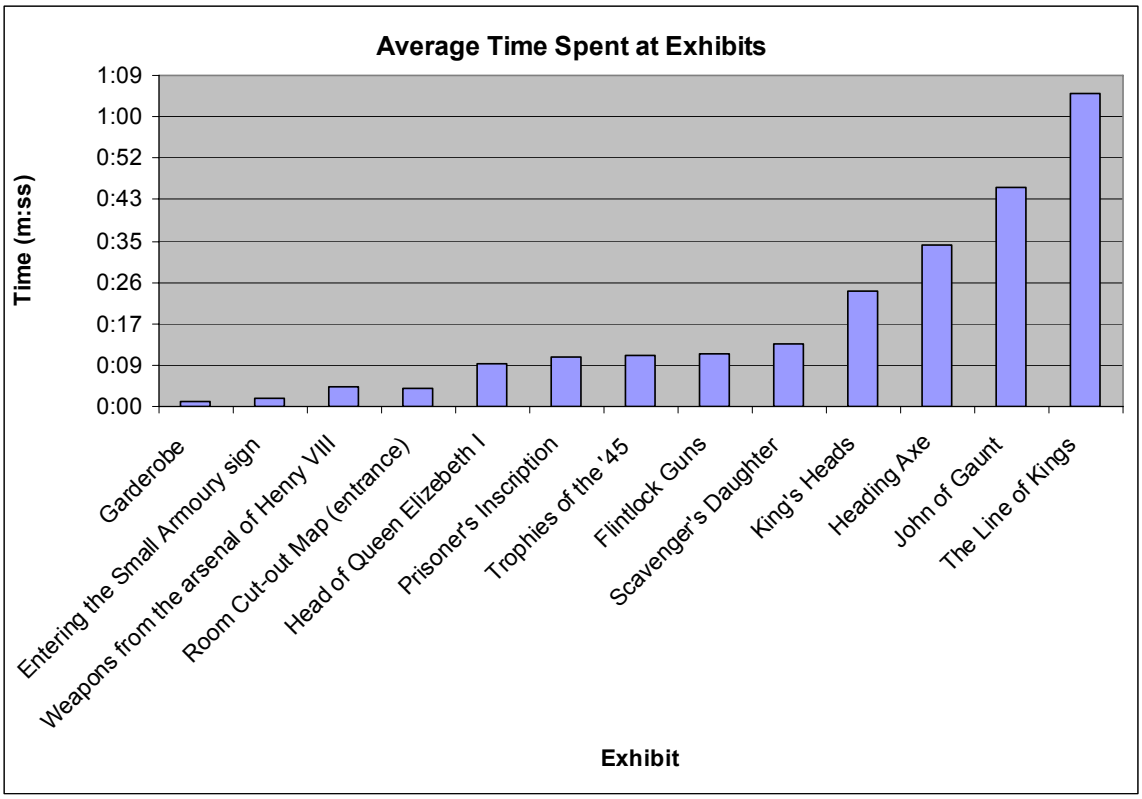

Figure 4 - Average time groups of visitors spent at exhibits on the entrance floor of the White Tower

Very few of the visitors observed viewed the Garderobe, Fireplaces, and Miniature Cannons exhibits, and even those visitors that did examine the exhibits spent much more time viewing others in comparison.

Our observations revealed statistics about how much attention labels and exhibits received. Visitors, even those who spent relatively large quantities of time viewing exhibits, ignored many labels. On average, visitors spent less than one-minute viewing exhibits, and the majority of exhibits received less than thirty seconds of an individual visitor's attention. We also found that visitors averaged approximately 40% of their time spent on the floor not observing any particular exhibit. When not observing the displays, visitors generally spent time traversing the museum; in some cases, we noted that visitors, in what appeared to be confusion, would retrace their steps in attempts to find alternative routes through the floor.

4.1.2 Visitor Characterization Data

Our visitor characterization data provided a view of the gender and ages of White Tower visitors. Our interviews (3.1.2.1) showed that the Tower of London is much busier

during the summer, holidays, and weekends. The White Tower sees a higher number of visitors during these periods, and we observed that the number of visitors tripled during the half term holiday, from approximately 200 people per hour to over 650 per hour.

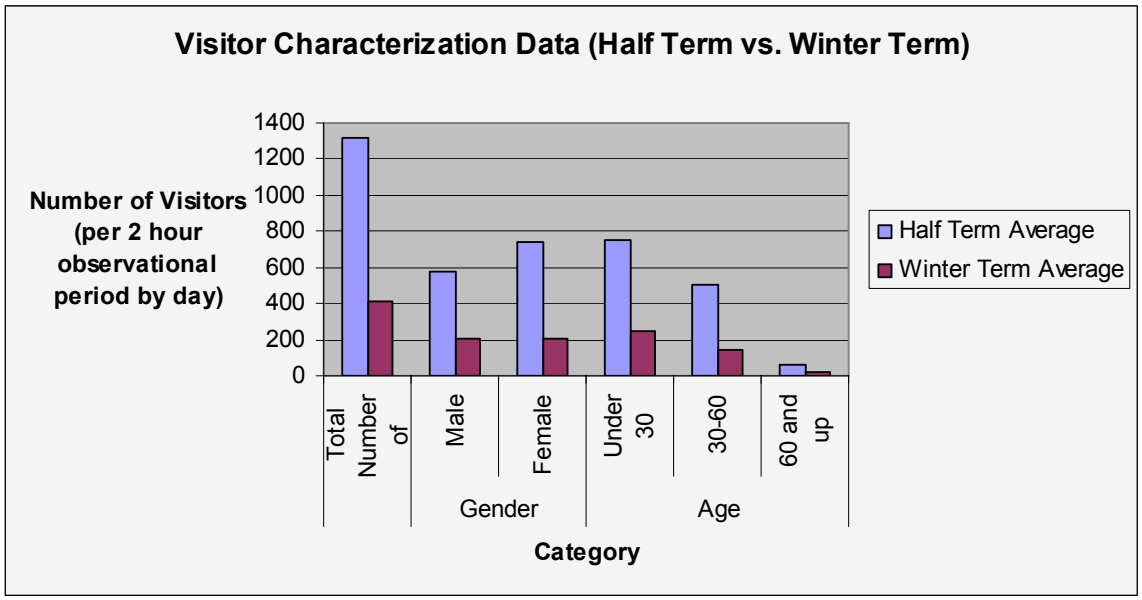

Figure 5 - Total visitor profile based on observational data.

As shown in Figure 5 there was a nearly equal distribution of male and female visitors during the winter terms. However, we observed that during the half term holiday there were more female visitors than male. In addition, we noted the approximate age group of the visitors and found that 60% of the visitors were under 30, while individuals above 60 only made up 5% of the total visitors. The complete list of data, separated by day, is located in Appendix G.

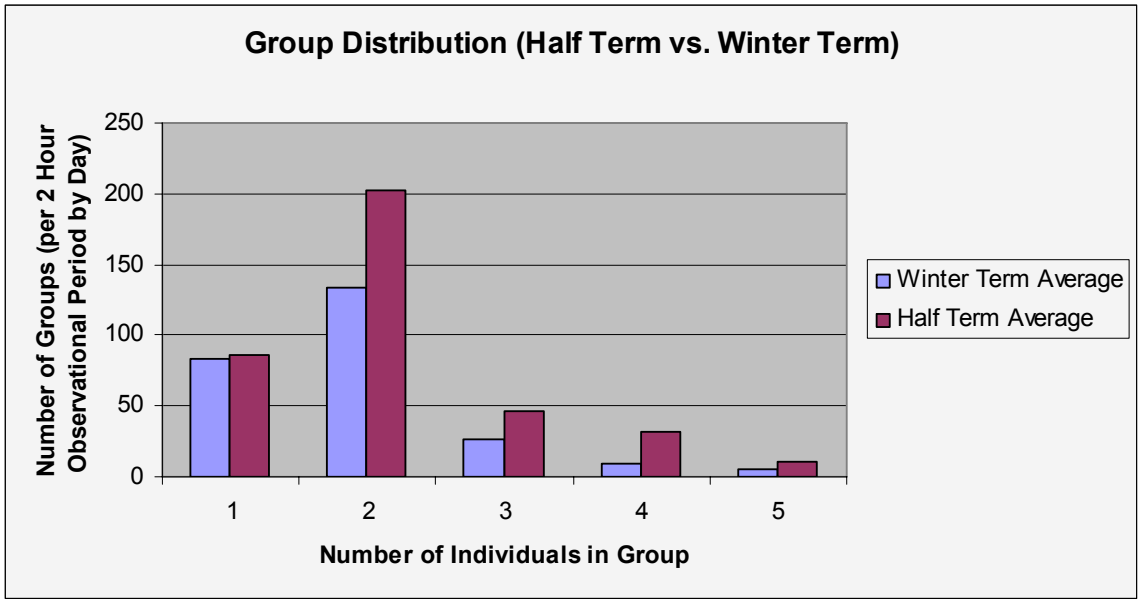

Figure 6 - The distribution of groups by number of group members.

Our team also wanted to understand how many individuals visited the Tower of London individually or in groups to add to our visitor profile. The data presented in Figure 6 shows that two-person groups made up 51% of all groups, while solo individuals, the second most common group size, made up 31% of the total. Three-person groups accounted for 10% of the total. The rest of the data (see Appendix H) includes groups ranging from four member groups to school groups of 31 individuals.

4.1.3 Attendance Variation Observations

Our team identified times of visitor congestion at the Line of Kings exhibit by observing visitor flow fluctuations in two-minute intervals. We collected results between 11 AM and 3 PM on several days, which allowed us to discern times of high visitor traffic. We selected the times to observe based on interviews with Tower of London staff about high traffic hours at the White Tower, and we arbitrarily chose the days to collect data. We also chose to observe visitors on a weekend during school half term to collect information that may represent high tourism visitor numbers.

Visitor numbers never exceeded 45 visitors in the exhibit at one time during regular winter month observations. However, we observed over 100 visitors at one time in the exhibit during half term observations. Interviews with Tower of London warders

indicated that during the summers, holidays, and weekends when more people enter the White Tower, more congestion occurs.

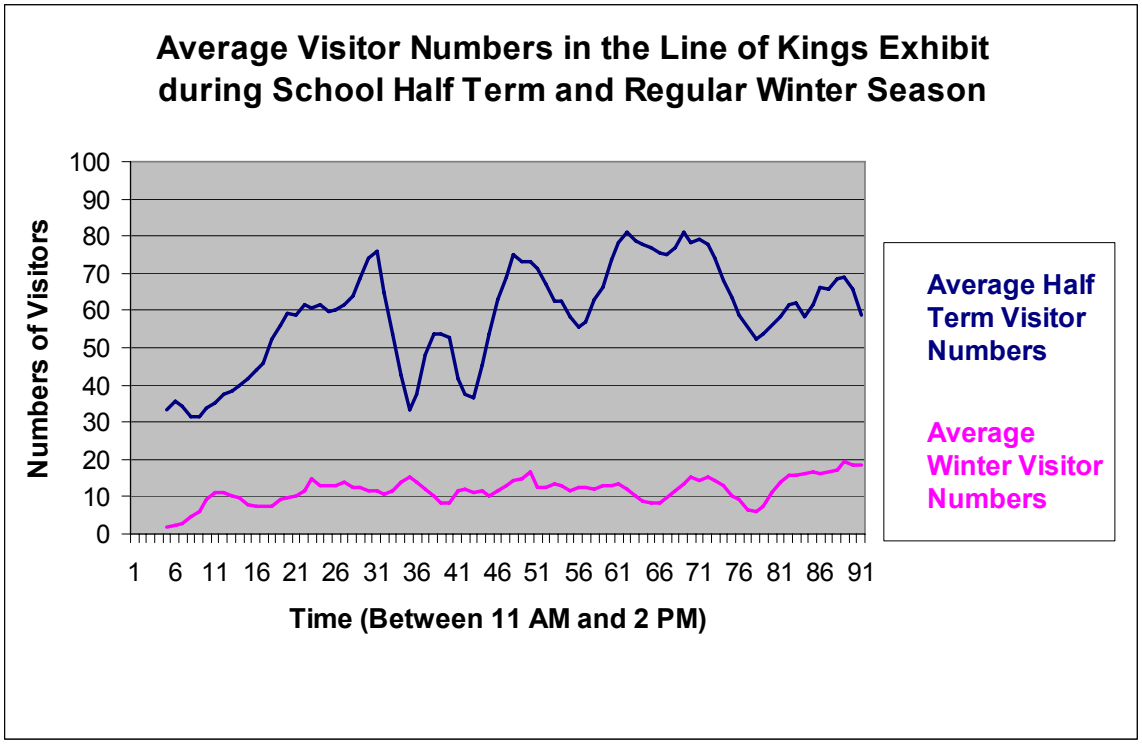

Figure 7 - The average visitor flow of two-minute intervals during winter months (22 January, 25 January, and 1 February) and school half term (15 February and 18 February). The graph represents a moving average over five periods.

Our observations suggest that fewer than fifteen visitors in the exhibit allows for a comfortable and accessible exhibit experience. During winter months and school half term, we observed lower numbers of visitors in the exhibit during morning hours. Specifically, we observed on 1 February 2007 no visitors in the exhibit area until 11:10 AM. However, we observed an increasing trend of visitor numbers in the afternoon hours, indicating more visitors tour the White Tower in the afternoon. Figure 7 depicts the increasing trend, particularly in the school half term average where the number of visitors increases from 34.5 visitors to 60 visitors in the Line of Kings exhibit hall between 11 AM and 2 PM.

4.1.4 Off-site Interviews

By interviewing staff at other museums in London, we gathered information on existing archival methods and tools, and suggestions for improving them. Prior archival

methods included labeling artifacts with codes and keeping the codes in a written index. However, many museums have turned to digital archives to maintain records easily and efficiently. After conducting interviews with the members of the staff at the Wallace Collection (Appendix I), the Museum of London (Appendix J), and the Imperial War Museum (Appendix K), we learned there are several commercial software products such as MuseumPlus, Oracle, and Multimymsi that software companies customize for specific museum archives. These customized tools allow archives to include digital photographs, label text, artifact descriptions, or any other information requested by the museum staff. The Imperial War Museum uses Adobe Photoshop, a more common software product, for image processing. The Museum of London also used common software, Microsoft Excel, for some data entry.

The museums we visited were in the process of entering data into their digital archives; however, all tools focused on individual artifacts, rather than entire exhibits. In our tool development, we started with a representation of the entire museum, then its exhibits, then specific artifacts within the exhibits. Thus, we created our tool as a digital archive, as well as a virtual tour.

Further off-site interviews produced feedback from international students testing the virtual tour. We asked the students to interact directly with the tour and to explain problems or confusion they encountered in the tool. Students offered suggestions on visual appeal, contextual relevance, navigation confusion, and layout clarity.

We created the virtual tour in a two-dimensional view of the White Tower. The international students suggested a three-dimensional tour would be more engaging and attractive for visitors. In addition, each student suggested the staff enter more pictures of the museum to provide a panoramic view of the museum. Students also suggested the label information was valuable, but text describing the exhibit importance and clarifying navigation through the tour would enhance the visitor experience.

Students commonly found the green buttons to be difficult to view, although the blinking buttons help to clarify navigation. Students recommended that tool enable staff to adapt the green buttons. The students also commented that the “GO IN” button caused confusion on entering the floor layouts and exhibits. Despite navigational problems, each student claimed the layout was clear and easy to understand.

4.2 The Tool

Our project resulted in a digital archival tool for the Royal Armouries' staff as well as a framework for a future virtual tour and exhibit-planning tool for the Line of Kings exhibit.

4.2.1 Archival Tool

The archival tool we created includes program features to incorporate the Royal Armouries' staff's needs and allow for a user-friendly, visual, and dynamic database. Results from interviews guided the design of this tool, and feedback evaluation sessions tested the requirements we developed.

4.2.1.1 Staff Needs

We designed our digital tool to accommodate the requests made by the Royal Armouries' staff, and we considered suggestions from members of other museums' staffs. The interviews with various staff members provided information that guided both high and low level development of our tool; we consulted museum professionals on general suggestions for archival tool features and specific options they recommend we include in our own.

The interviews with the Royal Armouries staff provided useful information regarding tool interactivity and complexity, allowing us to create a user-friendly, adaptable product customized to the Royal Armouries' staff's needs. Bridget Clifford and Mandy Martin-Smith—the Curator of the artifacts at the White Tower, and Education Officer, respectively—provided the initial specifications for our tool, and Clifford provided further clarification of the staff's requirements for the archival aspect of the tool. We supplemented the information gathered from formal prototype demonstration sessions with informal interviews that we conducted when necessary. These interviews provided very precise indications of staff members' preferences about the layout of visual elements in the tool's interface, as well as direction for our implementation of the underlying flow of information in the framework of the tool. Specific elements resulting from these interviews include the placement and viewing style of the hierarchical

navigation interface (the tree on the left hand side of the interface), the look and feel of icons and buttons, and the use of the new Royal Armouries' logo throughout the program.

4.2.1.2 A User-Friendly, Visual, and Dynamic Database

Important features requested by the Royal Armouries' staff included a user-friendly interface, a clear visual flow of the tool, and a dynamic, adaptable program for archiving, and our tool exhibits these characteristics.

Any computer user is able to operate the archiving tool due to the user-friendly interface integrated into the tool. The application follows standard conventions familiar to users of many current day programs, and the interface features menus, tabs, navigation displays, buttons, images, and text as seen in the screenshot below.

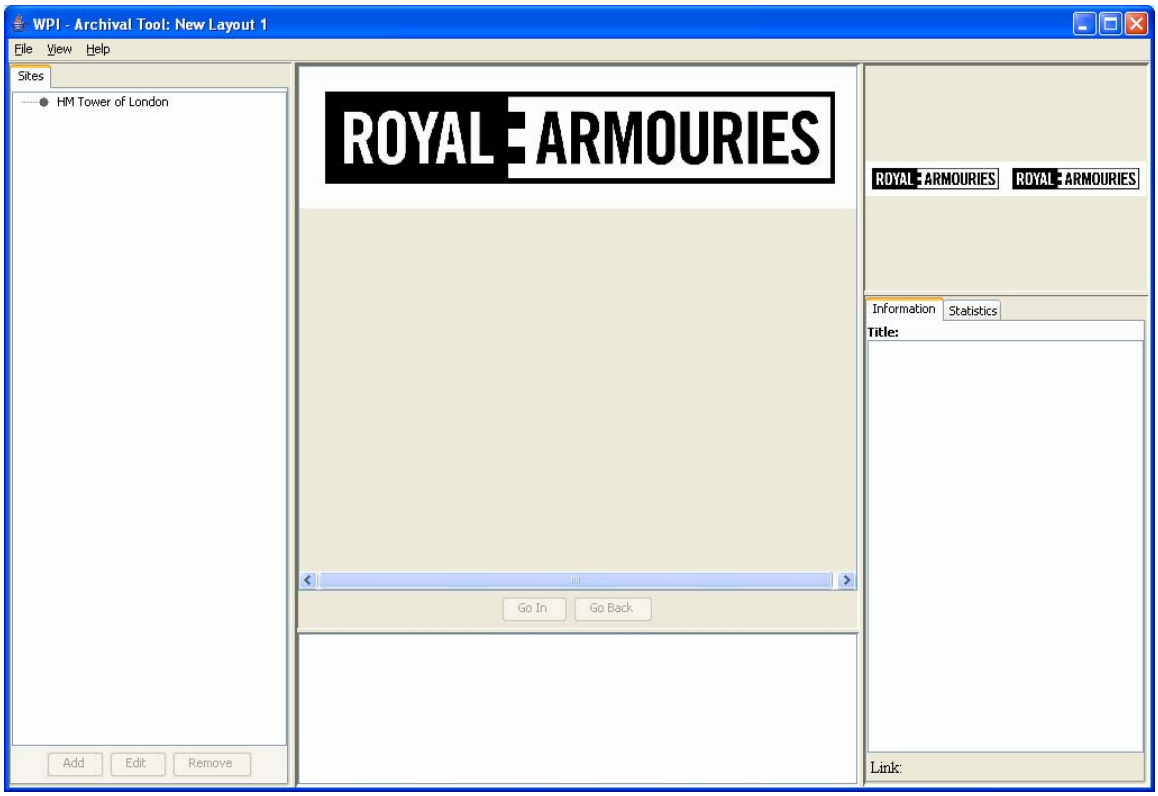

Figure 8 - Opening screen of the archival tool.

Users can configure the interface to run on Microsoft Windows and Linux operating systems, as well as any other system that supports the Java Runtime Environment.

The interactive photographical interface provides the user with a clear navigation system. The program displays user-specified images in the large central area of the interface, and users may distinguish elements of the images with buttons, which in turn

act as navigable links to sub-images. The combination of this visual interface with other selection paths provides users with multiple methods of accessing content areas quickly and easily.

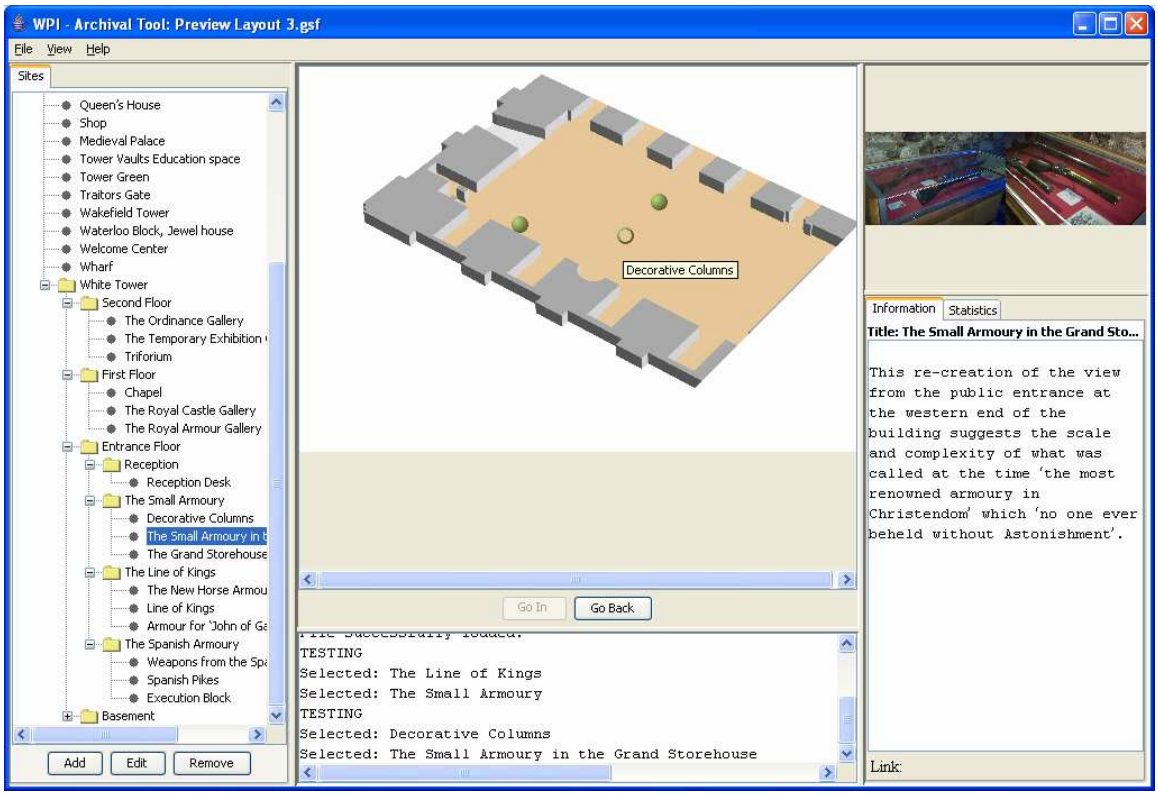

Figure 9 - Screenshot of a subsection under the White Tower in our archival tool.

Our archiving tool allows the user to adapt program features and to modify and save information on the Tower of London. Users can append, alter, and delete all information they find in the program—from text and pictures to the hierarchical layout of the museum. Users access each of these components through a Modification Panel, seen in Figure 8 below; each field is associated with an input window that allows users to make appropriate changes using conventional file opening and modification schemes.

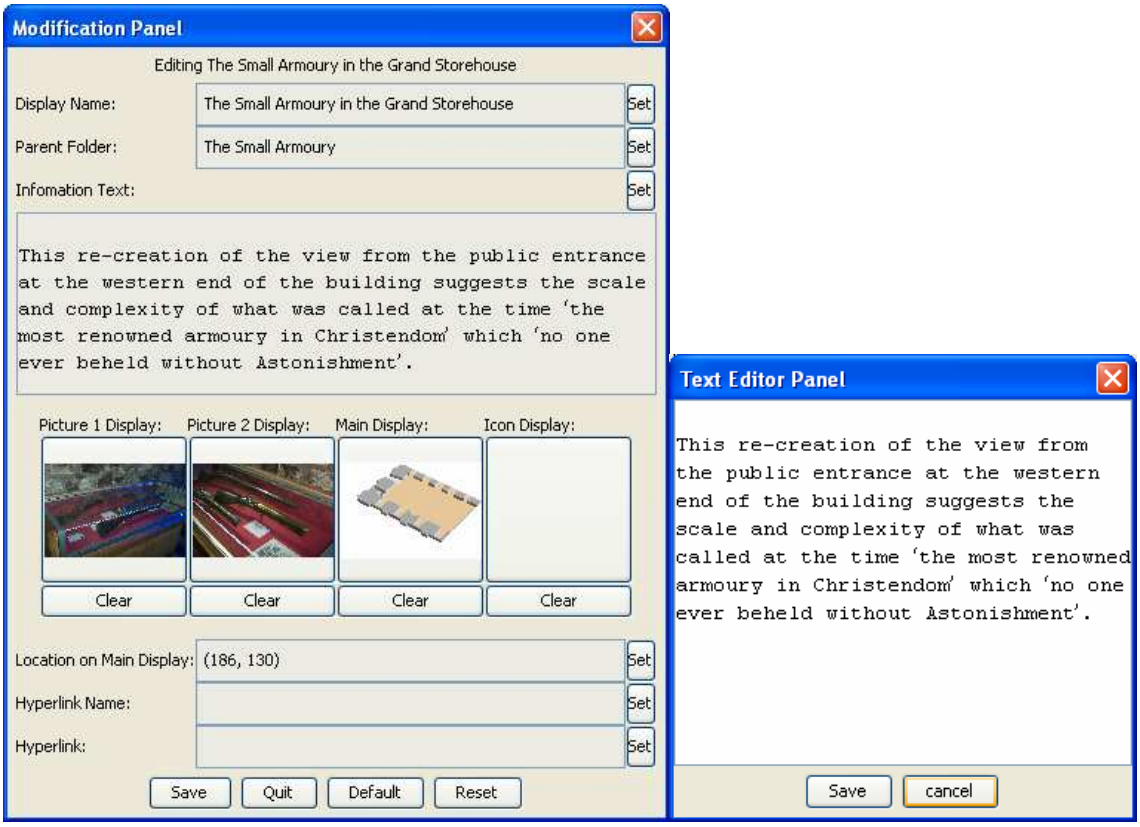

Figure 10 - The edit screen (left) and the text modification box (right)

Users can save the changes they make, and the saved files are loadable on any computer running our tool.

The tool also features a data-entry tab that allows users to enter statistics and visitor flow information. This feature, like all other editing features in the archival tool, is not available in the virtual tour.

4.2.2 The Virtual Tour

Accessibility is a focus of our online portion, and we implemented content and formatting specifications to ensure that the online aspects conform to general web accessibility guidelines that allow ease of learning for every individual.

The virtual tour is an extension of our archival tool that contains the same basic features, but limits the user's ability to edit of any of its features (see Figure 11).

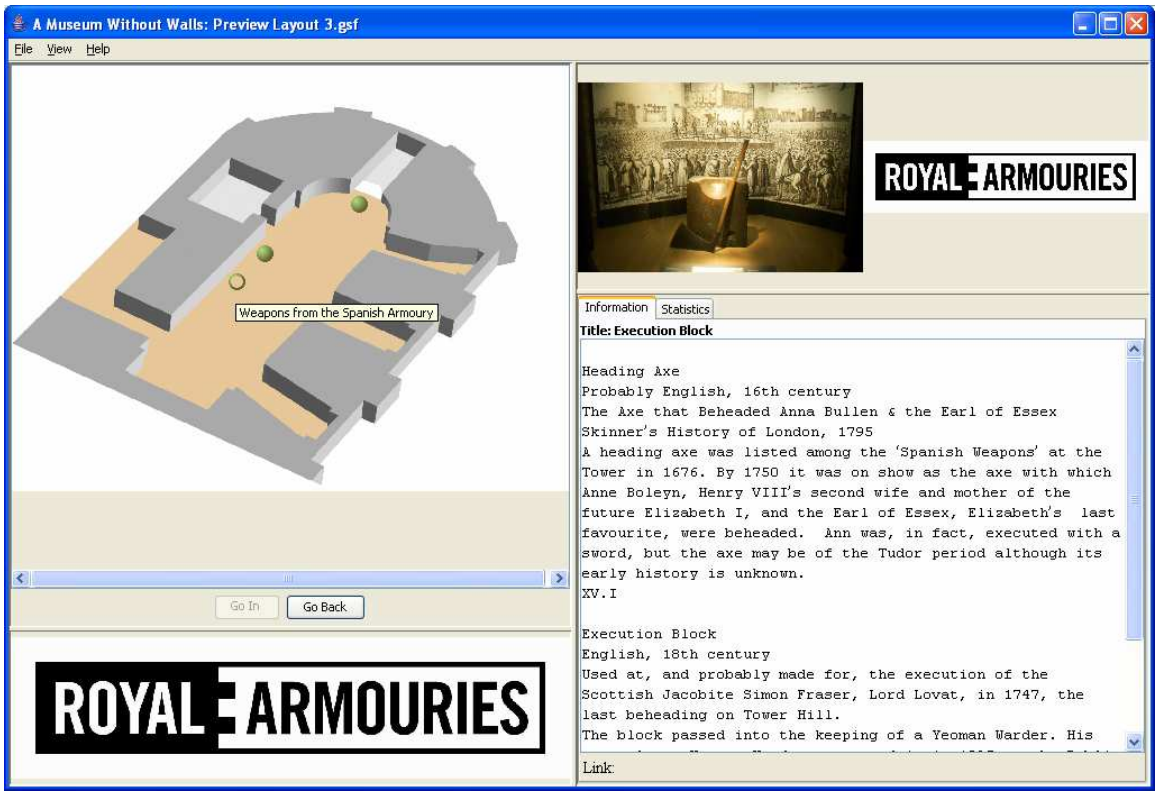

Figure 11 - Sample from the Virtual Tour

We made the tool contain adaptable aspects to serve as a prototype virtual tour for the staff to build upon in future endeavors.

Our tool is compatible with the Microsoft Windows operating system and is available for download worldwide from the Royal Armouries' website. A user can download the tool in two parts. One part contains all of the installable functions such as the executable file and the Java installer, and the other part contains the pictures and text used by the program. The interface is set up in such a way that it incorporates the new branding of the Royal Armouries.

Our tool is an educational gateway to the contents of the White Tower for the public by providing the information contained in the White Tower as images and descriptions of exhibits and labels. The use of pictures and descriptions simulate a feeling of being in the museum.

4.2.3 The Virtual Line of Kings

We gave the archival and virtual tour aspects of our tool higher priority than the virtual Line of Kings, and we were unable to produce a fully interactive digital representation of this exhibit due to time constraints. However, we did develop an on-paper layout for the tool (see Figure 12), and we gathered many of the images that would be included in it. This layout and collection of images allows any subsequent Worcester Polytechnic Institute teams or other groups to resume development of the tool where we left off.

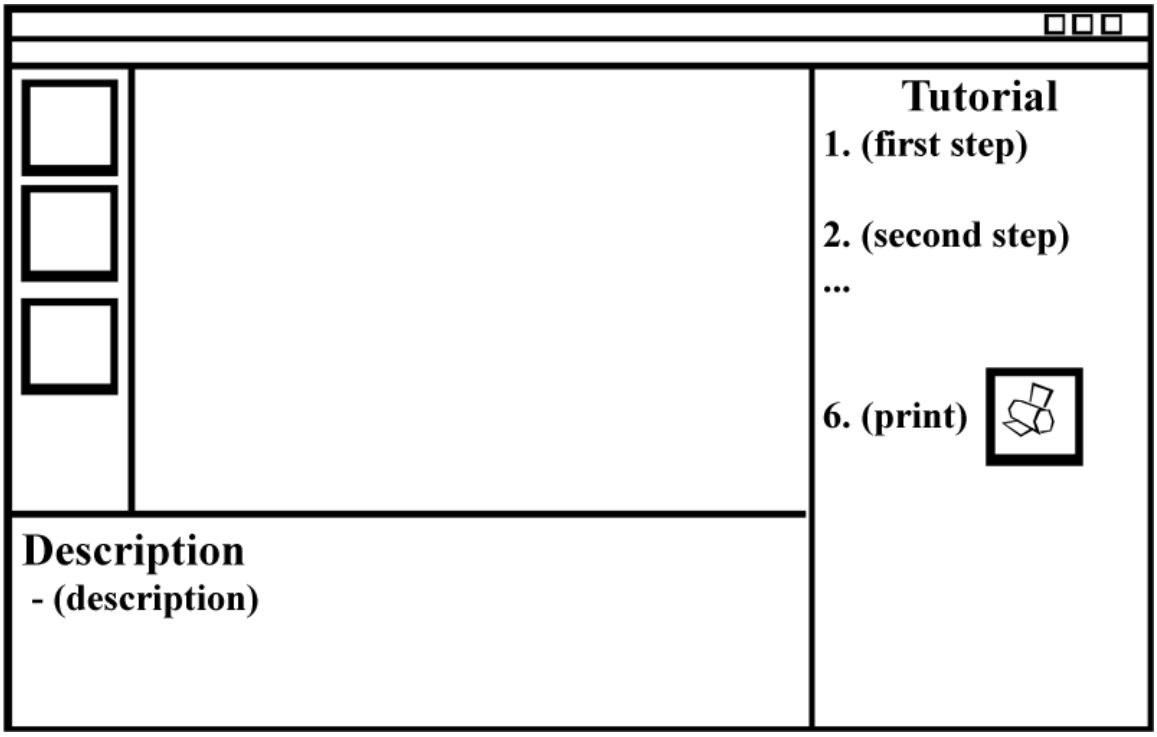

Figure 12 - Layout for the Virtual Line of Kings.

5. Discussion

The discussion section contains a comprehensive study of the gathered data, answers the defined research questions, and identifies and examines common themes that became apparent during our project. We divided these sections into the analysis of our social research and a discussion of the aspects of the tool we created.

5.1 Social Research

The data produced by our social research showed visitor flow issues on the entrance floor of the White Tower, the common types of visitors to the Tower of London, and features to include or change in our tool.

5.1.1 Ant Trails

The data produced by our ant trail observations indicated that some exhibits, especially those in the Line of Kings area, received much more attention than other exhibits. The proximity of two of these exhibits, namely the Line of Kings and John of Gaunt, contributes to visitor congestion near them. Areas of congestion appeared to motivate other visitors to seek out alternative exhibits, decreasing both the amount of time they spent in the problem area and the likelihood that they would read exhibit labels.

5.1.2 Visitor Characterization Data

Our observations show that the majority of visitors are those we approximated to be under the age of 30. The Royal Armouries' staff can use this information to communicate the information within the museum to this audience. Conversely, the staff can cater to the visitors older than 60 to try to get these people to attend the museum.

5.1.3 Attendance Variation Observations

Through observing the visitors every two minutes in the White Tower, we gained valuable information on exhibit accessibility during specific hours of the day and under different visitor crowding conditions. The White Tower is most accessible during the morning and early evening hours. More visitors tour the museum during the summer months and school breaks, as was indicated in our interviews with Tower of London staff. The increase in visitor numbers during these times leads to visitor flow congestion, confusion about displays, and an incomplete visitor experience.

5.1.4 Interviews

The interviews we conducted at other museums helped to clarify the importance of digital archival tools. Many museums find using digital archival tools to be the most efficient method of archiving due to the dynamic, organized, and user-friendly interface,

which a software company customizes to meet individual museums' needs. Digital archives allow the user to enter new data, modify old data, view artifacts photographically, read label texts, and more. We encountered an example of a customized digital archive at the Wallace Collection museum. The Wallace Collection's tool included descriptions and photographs of specific artifacts as well as label information; however, they kept no record of display descriptions. A lack of display information did not hinder the effectiveness of the tool for the Wallace Collection's archive, as the public viewing the archive expect mostly two-dimensional visual displays. Allowing the public to view the archive, as in an online virtual tour, improves accessibility.

As Roy Stephenson mentioned in an interview we conducted at the Museum of London, archival tool users can obtain information quickly, may view already completed research, can evaluate previous history and artifacts, and may gain a greater appreciation for the past and the present through their research. Although previous forms of archiving provided a wealth of information to the visitor, they restricted the user's ability to conduct research due to the slower method of a manual index and card catalog. The technology used in archives today allows visitors to collect information directly and instantly from a computer or other source. Therefore, digital tools enable users to compile comprehensive studies in a short time period, as well as broadening the user's appreciation of history.

5.2 The Tool

The knowledge we gained from our tools developmental stages in addition to information gained from its evaluations, we combined into the following sections. These sections detail the themes and general ideas that we noticed, and we have separated them into the different aspects of the tool we created: archival, virtual tour, and virtual Line of Kings

5.2.1 Archival

Our evaluation of the archival tool showed that it is an effective addition to the Royal Armouries' staff's methods of maintaining exhibit and museum archives. Further

interviews and demonstrations of the tool showed that it is far more effective than previous archival methods used by the staff that lacked interactive visual views of exhibits and their layouts. While the representation of the museum we provided is not a complete illustration of the items displayed in the White Tower, the fast, efficient, and dynamic nature of our tool allows the staff (or other project groups) to create such a portrayal in a much shorter span of time than that previous on-paper methods would require. The visual elements of our tool allow the staff at the White Tower to learn from past exhibit layout mistakes and successes so that they may make improvements to displays in the future. In spite of these benefits, the visualization of the White Tower is only a step in the process of conducting a redisplay, so there is no guarantee that our tool will have a significant impact on the efficiency of upcoming reorganizations of the exhibits.

5.2.1.1 Wayfinding and Accessibility

It is difficult to estimate how successful the archival tool will be in the future, but we concluded that our visitor flow data and the visual archive would help in future redisplays. Interviews with the Royal Armouries' staff gave us information on the impact of our tool on their efficiency as a museum. According to Bridget Clifford, the Curator of items within the White Tower, our tool is a huge advancement from previous archival methods used at the White Tower that lacked completeness, were not digital, and did not include many photographs. Our tool incorporates a visual visitor flow representation that assists the staff in resolving problems in wayfinding and visitor congestion in future redisplays. We provided the Royal Armouries' staff with a sample image that displays the most common visitor flow through the entrance floor of the White Tower, as seen in Figure 13.

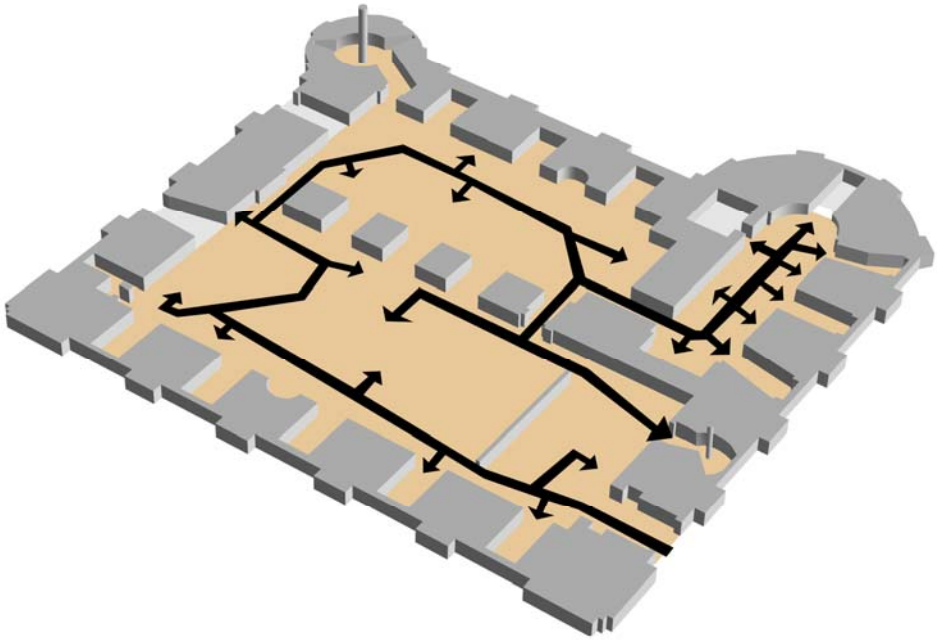

Figure 13 - Common Visitor Path through the Entrance Floor of the White Tower.

Increasing accessibility of future displays will allow future visitors to experience the White Tower with a clear pathway and the ability to view all exhibits more comfortably with little confusion or congestion. A comfortable environment is essential for effective learning and allows self-motivated learners to explore freely, while absorbing the maximum amount of information. Since museums are public centers of education, it is important for visitors to learn with little inhibition from their surroundings.

5.2.1.2 Learning from the Tool

Royal Armouries' staff can represent past museum layouts and hypothetical ones by taking advantage of the dynamic nature of our tool. This allows the staff to learn from past mistakes and successes and apply that knowledge to future designs. In particular, staff may examine past layouts for accessibility and visitor flow issues, and improvements to future displays in the White Tower based on these examinations will ultimately increase the accessibility of those displays.

5.2.1.3 Efficiency of the Tool

Our tool expedites the planning and analysis phases of museum redesign but does not necessarily result in faster redisplays. Digital archival methods serve the user more efficiently than paper methods as the user may view needed information by simply clicking a mouse. In addition, a digital archive displays information in an organized fashion and allows the user to change information cleanly and easily. For these reasons, many museums in the London area have considered incorporating or have already implemented digital archiving tools into their archival systems.

Our program includes features to record wayfinding issues and exhibit planning elements, which were previously to the Royal Armouries' staff. Although a professional software company may create a more advanced archiving tool, we customized our program to incorporate suggestions and requirements from the Royal Armouries' staff. Using our tool allows the staff to examine visitor flow problems as well as to plan exhibits according to previous exhibit evaluations. Therefore, our tool will result in better-planned exhibits directly, and increased education indirectly.

5.2.2 Virtual Tour

The virtual tour we created allows the public to access White Tower information through viewing floor layouts, exhibit and artifact pictures, and label text. The virtual tour will be available online after the Royal Armouries' staff creates a complete tour through the tool. We interviewed international students to evaluate the effectiveness of the tool for a variety of users (see Appendix L). Three of the four students visited the Tower of London prior to viewing the virtual tour. The students, except for the individual from France who did not comment, agreed that with complete information, the virtual tour would be a good representation the museum.

By observing the students interacting with the virtual tour, we noted that navigation of the tool proved difficult at times. Although students commented the layout was clear and the blinking buttons helped in identifying location in the tour, the students appeared to overlook the "GO IN" button when trying to enter floors or exhibits. This problem resulted in confusion of navigation and users exploring limited sections of the tour. In addition, all students requested more pictures of the White Tower to provide the

visitor with a panoramic view of each room. To enhance the visitor experience and increase communication of White Tower information, it is imperative that future tours incorporate more aesthetic and interactive aspects into the tool.

6. Conclusions

The Royal Armouries organization maintains a collection arms and armor at museums in Leeds, Fort Nelson, and the Tower of London in the United Kingdom as well as a museum in Louisville, Kentucky in the United States. The Royal Armouries' staff at the Tower of London realized the need for an adaptable and efficient archival tool upon planning their five-year museum redisplay in the White Tower. Worcester Polytechnic Institute assigned our team to create an organizational tool for the Royal Armouries' staff. The tools we created to resolve the Royal Armouries' dilemma included a digital, adaptable, and user-friendly archival tool, a virtual tour directly related to the digital archive, as well as a framework for virtual representation of the Line of Kings exhibit. We collected and analyzed observational data results and technological development results, leading us to a series of conclusions and fall into two categories: accessibility and education. In addition, we evaluated the impact of technology on accessibility and education, as they are important topics in society.

6.1 Accessibility

The Royal Armouries plans to redisplay the exhibits of arms and armor contained in the White Tower during the next five-years. The archival tool we created allows the staff to enter data on current display layouts, view visitor flow problems and statistics, as well as maintain records of artifact and past exhibit layouts. The tool incorporates suggestions, comments, and preferences from the main audience of the tool, Bridget Clifford and Mandy Martin-Smith. The technology we created demonstrates its organizational advantage for the five-year redisplay plan through its ability to adapt, its user-friendly interface, and its interactive quality. Users can add and remove areas of the archival tool for public use. The virtual tour we created appears similar to the archival tool; however, the virtual tour contains restrictions, such as no access to the log box, tree panel, and statistics tab.

Our virtual tour tool enhances the accessibility of the White Tower to a variety of audiences. By creating an online application containing the White Tower exhibits, we increased the range of visitors touring the White Tower. The tool allows disabled individuals and non-visitors to gain access to information about the museum, without physically entering the Tower of London. Users may download the digital representation from the Royal Armouries' website, and explore the museum at their own leisure. Therefore, any individual around the world with access to the Internet may view the arms and armor within the White Tower. Advancements in technology, such as the Internet, allow knowledge to be publicly available and widespread to many societies. By providing more visitors with information on the White Tower, our tool increases public knowledge of the arms and armor displayed in the Tower of London.

By observing the use of our tool by its intended audience—including international students and the Royal Armouries' staff—we gathered information supporting the effectiveness of the accessibility of our tool. Due to limited time for evaluation, our team was unable to evaluate the impact of the online virtual tour. However, observations of international students using the tool provided insight to the effect the virtual tour may have on international visitors who access the tool online. The international students confirmed that the tool represented the White Tower in an educational, interactive, and effective manner. Therefore, we predict that an online virtual representation of the White Tower will also have a positive impact on accessibility.

6.2 Education

As mentioned above, our archival tool and virtual tour contribute to public learning directly and indirectly. The archival technology we created allows the Royal Armouries' staff to evaluate displays, and to propose clear, informative, and entertaining redisplays. We predicted the redisplays created by the Royal Armouries' staff would improve informal learning by encouraging visitors to explore the improved museum layout and interact with exhibits. In addition, we predicted the enhanced redisplays would contribute to formal learning by enticing more school groups to visit the White Tower through increasing interactivity of the exhibits. The future redisplays will increase the success of learning in the museum as well as the visitor experience in the museum.

Our virtual tour and Line of Kings exhibit framework will also contribute to education at the White Tower. The virtual tour is interactive and international students, which the team interviewed, claimed the tool was user-friendly, provided a good layout of information, and showed excellent potential for future online use. Mitchell and Savill-Smith (2004) state, "the instant feedback and risk-free environment invite exploration and experimentation, stimulating curiosity, discovery learning and perseverance." The technology of the virtual tour allows for rapid feedback and self-motivated exploration for millions of visitors with Internet access.

The framework for the Line of Kings exhibit provides a foundation for an interactive game incorporating arms and armor from various eras. We offered the Royal Armouries' staff ideas for the interactive game, which will directly affect formal learning by its use in the Education Centre classroom.

Our background research claims that people learn more from interactive and visual lessons than from static displays. Engaging and interactive displays of the White Tower gain more visitor interest; therefore, visitors obtain a greater knowledge of the museum due to their self-motivated learning. Furthermore, computers allow for constant interactivity as the users explore the interface. Our tool combines a user-friendly and engaging computer interface to generate the visitor's interest and awareness of the contents of the White Tower

7. Recommendations

Our team offers the following recommendations to the Royal Armouries' staff for future implementation. The following section contains our ideas on potential approaches to improving the museum based on our observations, and includes methods for extending our tool.

7.1 Improving the Museum

Our observations revealed that areas of the entrance floor to the White Tower experience congestion and crowding even during non-peak visitation times. Most of the visitor flow problems on the entrance floor result from crowding due to exhibit layout issues, large groups of visitors, and a tendency for individuals to queue at displays.

Three areas contributed to bad visitor flow on the entrance floor: the combination of the Line of Kings and John of Gaunt exhibits, where visitors tend to linger; the doorway to the Spanish Armoury, which experiences two-way visitor traffic; and the doorway connecting the Line of Kings area to the entry area leading to the stairs, where some visitors disrupt the flow by proceeding in the wrong direction. We recommend that the Royal Armouries' staff relocate some of these popular exhibits to locations that do not experience as much congestion. We also recommend that the staff place signs in key locations to inform visitors of the direction the staff intends them to travel.

Large groups, such as school groups, also cause problems with visitor flow. We recommend that these groups pass through the museum under the guidance of a warder or in smaller subgroups to prevent excess crowding of individual exhibits.

Labels are another area of the museum the Royal Armouries' staff can improve during the future redisplays. Communicating information on the artifacts to the visitors are prominent problems that the museum faces. The information presented on the current labels is clear and very well written, but visitors have a tendency not to read them. A method to increase awareness of labels is to create situations where the museum encourages visitors to read the labels. We recommend the creation of a game that incorporates the labels in its infrastructure. A possible game would be a scavenger hunt requiring visitors to find certain artifacts and gather information from the labels in order to solve a puzzle. The staff can create this game for adults and children with different stories and can award items upon completion.

We found the lack of interactive exhibits within the White Tower to be a possible impediment to effective learning. One of the most popular exhibits we noted was the John of Gaunt exhibit. This exhibit contained interactive elements, mainly the ability of visitors to compare their height with that of the armor. We recommend that the Royal Armories' staff consider methods of increasing visitor interaction with exhibits, such as integrating audio and digital video elements into existing displays to provide feedback to visitors.

7.2 Extending the Tool

Our team evaluated areas of the tool that the Royal Armouries' staff may improve. Our team based the following recommendations on information from interviews and evaluation of the tool.

7.2.1 Other Locations and Purposes

As suggested by Royal Armouries' staff members, we recommend that the staff implement the archival tool at other Royal Armouries' locations and for organizational purposes other than archives. Royal Armouries' locations at Leeds, Fort Nelson, and Louisville, Kentucky may benefit from the exhibit organization the technology offers.

We recommend that the staff may use the archival tool for other purposes. The adaptable and user-friendly characteristics of the tool we created makes it useful for other needs such as photographic, textual, or audio organization. The staff may apply the technology beyond archival methods; for instance, the staff could replace a newsletter detailing updates to the White Tower with a virtual tour file made.

7.2.2 Complete Virtual Tour

The tool we created provides a framework for a virtual tour; however, the tool does not contain a complete representation of the data of the White Tower and Tower of London. We suggest the Royal Armouries' staff consider working with the Historic Royal Palaces to enhance the tool, and to create a complete virtual tour of the Tower of London.

In addition to updating the tool's information, we recommend the Royal Armouries' staff create a more interactive and entertaining interface. For instance, the staff may consider changing button color on the maps, changing background color and effects in all screens, implementing interactive features in the exhibits and maps, and adding a search feature for specific artifacts. The Royal Armouries' staff may also increase user entertainment by creating a three-dimensional exhibit representation. Three-dimensional views of artifacts and exhibits will enable the Royal Armouries' staff to view complete designs from the past, and will enhance the staff's ability to create future displays. Other additions to the tool may include video or other multimedia

representations of the Tower of London. By enhancing the tool's features, the virtual tour will be a more efficient source of public learning and a valuable visitor experience.

7.2.3 Create Virtual Line of Kings and Other Virtual Exhibits

Our team created a framework for a virtual Line of Kings exhibit. In accordance with our team's primary goals, we recommend the staff create an adaptable Line of Kings scene where staff can interact with the screen by moving different armors between horses and evaluate the aesthetic and historic accuracy with each scene. As suggested by Mandy Martin-Smith, the staff may also implement an interactive scene in classrooms as an educational computer game. Children would learn formally through an entertaining and interactive computer game in which they would identify and create a solution to repair the misfit Stewart, Tudor, and Victorian armors.

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Appendix A - Sponsor Description

Her Majesty's Tower of London has had a long history. Its construction began in the year 1066 under William the Conqueror's reign. It was built specifically to hold soldiers and armaments to protect the city of London. From 1327 to 1377, under the Reign of Edward the III the tower transformed into a cache for the English army and navy. In 1509, while Henry VIII ruled, much of the older armor and munitions including Henry's personal equipment were updated and moved from other armories and placed into the Tower of London. During the English Civil Wars, many other royal armaments were brought to the Tower from Greenwich Palace. During its active service as a supply chain, only certain visitors were allowed to marvel at the British armory, however after Charles II restored it in 1660 the public was also allowed to view it for a small fee. After a great fire in the mid 19th Century, the ordinance at the Tower of London was destroyed. The Tower was no longer able to supply the English army and navy. Since then the Tower of London has been used as a museum.

Museums in general are used to provide the public with scientific, historical, and artistic information and experiences, and serve as sources of informal education. Given its function as a museum, the mission of Her Majesty's Tower of London is "to promote in the UK and world-wide the knowledge and appreciation of arms and armour and of the Tower of London through the collections of the Museum and the expertise of its staff." Currently, the museum features displays of armaments dating from as early as the middle ages, to as recent as the 20th Century. Exhibits have featured many items owned and worn by royalty, such as decorative armors and weapons, and even the Crown Jewels.

Currently, Her Majesty's Tower of London is a fully staffed museum that is maintained by the Historic Royal Palaces (HRP) – an independent charity that takes care of many of the historic places in Britain. In addition to the Tower of London, HRP looks after four other historical palaces: Hampton Court Palace, Banqueting House, Kensington Palace, and Kew Palace. The organization is headed by the Board of Trustees of the Armouries, a group that convenes at least six times every year, and governs the organization's subcommittees (Audit and Finance, Remuneration, and Development and Design). Although they are owned by the Queen, and subsequently Parliament, the sites

HRP oversees receive no public funding, and depend entirely on the support of visitors, donations, and charity.[*]

Table 1 shows the budget breakdown for the Tower of London in the 2002-2003 fiscal year.

Table 1: Budget

Incoming resources	£7,599,000
Government grants	£6,286,000
Sponsorships/donations	£101,000
Contributions	£100,000
Trade	£804,000
Expended resources	£8,690,000
Salaries/employees	£4,028,000
Depreciation	£1,602,000
Fund balance	£47,837,000

During that year, The Tower of London had 195 employees to perform various tasks throughout the museum. Approximately 400,000 people visit the museum each year.

The exhibits at the White Tower are maintained by the Royal Armouries, and organization that preserves artifacts at three other locations—Fort Nelson, Leeds, and Louisville, Kentucky. Royal Armouries' staff also educates visitors to the Tower of London through programs that utilize the Waterloo Block's Education Centre.

[*] The organization is a charity, and the "Government grants" field of the following Budget table should not be confused with government funding; the organization applies for various grants (including those available from the government), but no public funding is allocated specifically for the organization.

Appendix B – Use Case Example

The following is an example of a simple use case that could be used during the development of the archival tool. Describing this sequence of actions during an informal interview could help determine the staff's general preferences for the interaction sequence.

Name: Add an Artifact
Identifier: UC1

Description:
Add a new Artifact to an exhibit or location

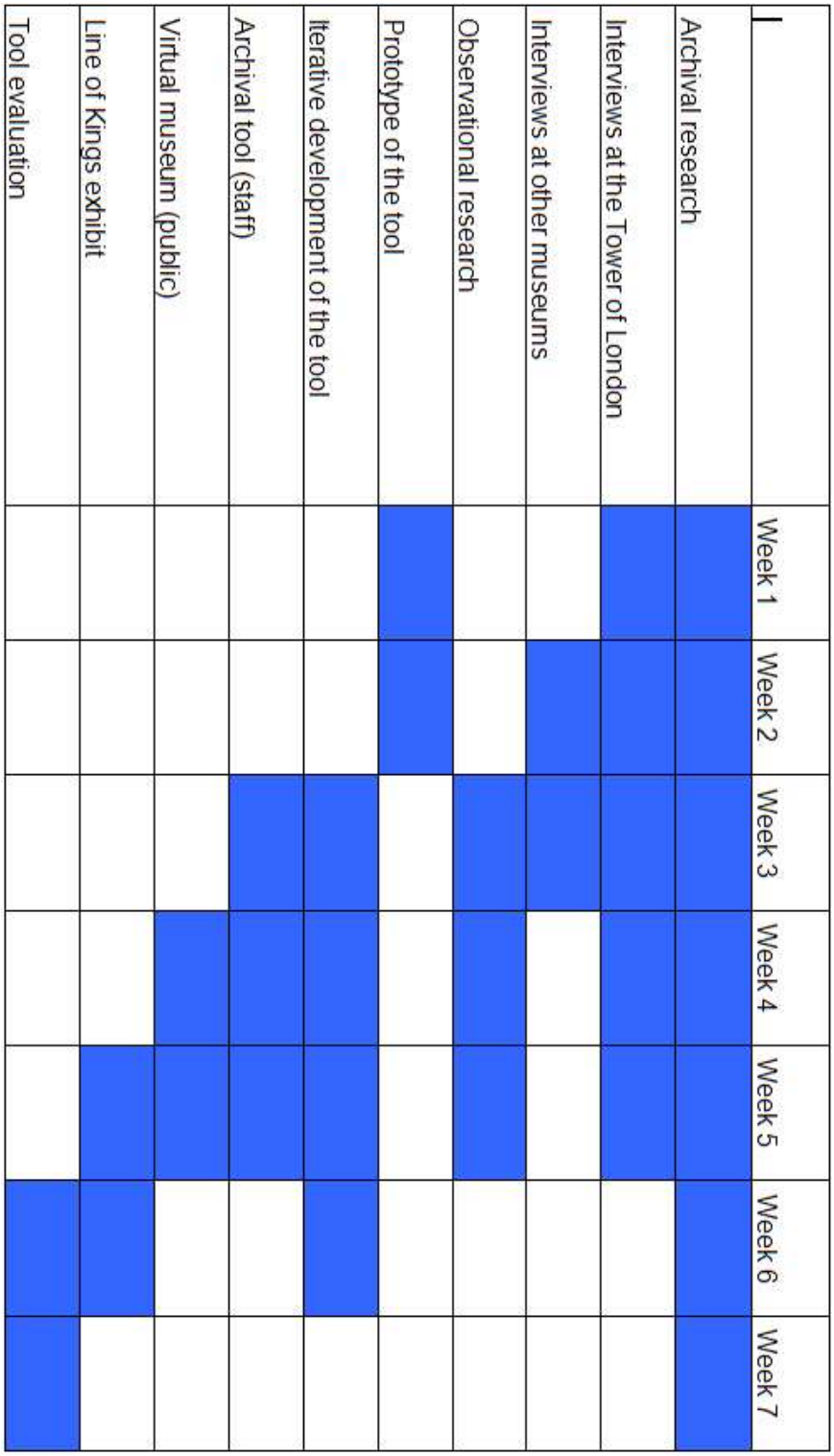
Preconditions:
The correct exhibit is open

Postconditions:
The artifact will be listed as part of the exhibit or location

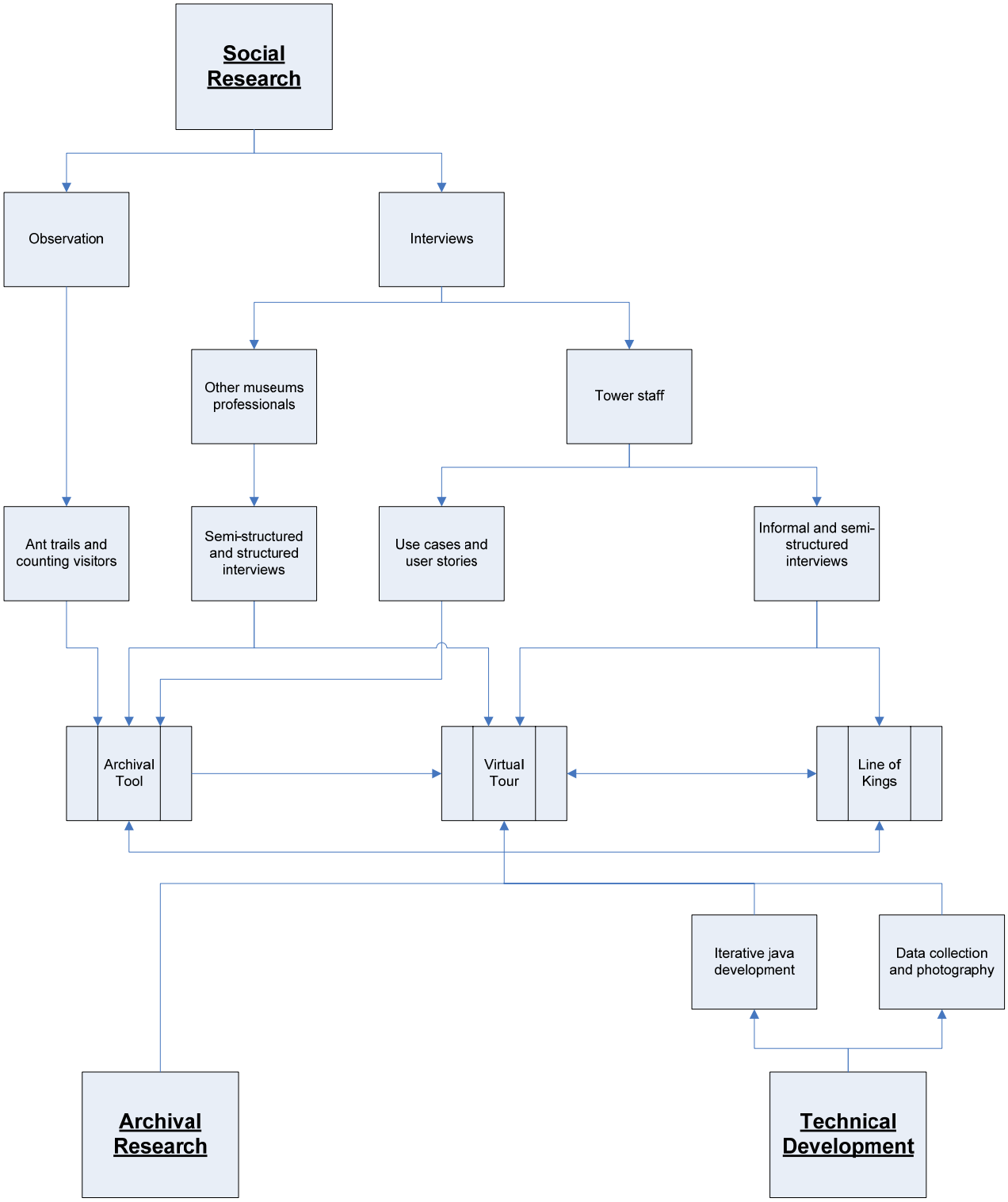
Basic Course of Action:

1. The use case begins when a user wants to add an artifact to an exhibit
2. The user opens a "Create New Item" dialog
3. The user enters name, description, and picture location fields
4. The system verifies the name (for duplicates), description (can't be blank) and picture locations (verifies file locations or inserts default placeholder images)
5. The artifact is added to the exhibit

Appendix C – Timeline



Appendix D – Methodology Flow Chart



Appendix E - International Students Interviews on Virtual Tour

Interview #1: American Student

Where are you from?
America

Have you visited the Tower of London?
Yes

Do you think this is an accurate representation of the information within the White Tower?
Once the information is complete, yes it will be an accurate representation. It may be more informational than the museum, because the visitors are more likely to read labels online since the artifacts will not distract visitors.

Is the tool easy to use and to navigate through?
Yes, except the "go in" button does not show clearly that there is more information further.

Does the tool provide all the information you would be looking for?
The entrances and exits on the floor plans may be useful to orient people who have visited the White Tower and want to retrieve more information.

Does the tool present the information clearly?
Yes, the layout is clear.

Did you have problems with using the tool?
The "go in" buttons are confusing. Green peas are difficult to see.

Do you have any improvements to suggest for the tool?
Add text description saying "click *go in button* for more detail" in the text window to provide more direction. Change the peas to different icons or colors.

Interview #2: Malaysian Student

Where are you from?
Malaysia

Have you visited the Tower of London?
Yes

Do you think this is an accurate representation of the information within the White Tower?
Yes

Is the tool easy to use and to navigate through?
Entering floors and exhibits is complicated because the "go in" button is not clear or eye-catching.

Does the tool provide all the information you would be looking for?
Yes, except more pictures and views of the Tower would be ideal.

Does the tool present the information clearly?
Bigger text would be helpful.

Did you have problems with using the tool?
Entering the floors and exhibits in tour was not clear.

Do you have any improvements to suggest for the tool?
Three-dimensional representation would be better and more attractive, especially if disabled visitors use tool, they may want to see more of the museum.

Interview #3: Japanese Student

Where are you from?
Japan

Have you visited the Tower of London?
Yes

Is the virtual tour an accurate representation of the information within the White Tower?
Yes, it is very similar to the White Tower. More pictures and information would help convey experiencing the museum. It cannot replace the actual White Tower, because the seeing the objects up-close and in real life is much different than staring at a computer screen.

Is the tool easy to use and to navigate through?
Yes, the blinking buttons are very helpful to keep track of location in museum. The tool bar with the view, file, etc. was a little confusing until Mike provided instruction.

Does the tool provide all the information you would be looking for?
The layout of the tool is great, although more pictures would be helpful to enhance vision of museum. The virtual tour in general is informative; however, visitors may not want so many words. A "tour" should show more pictures and represent the museum visually. Once staff complete information entry, it will prove more useful

Does the tool present the information clearly?
Yes, the layout displays information clearly and the blinking buttons provided helpful information on location in the tour.

Did you have problems with using the tool?
The pictures are too small, although after Mike demonstrated the adjustment of the picture window, the pictures became more visible and useful.

Do you have any suggestions for improving the tool?
Future users could improve attractiveness of the tool. Currently the tool is not very eye-catching or exciting. In addition, a zoom tool on pictures may be useful or more instruction on the picture window resizing tool.

Interview #4: French Student

Where are you from?
France

Have you visited the Tower of London?
No

Do you think this is an accurate representation of the information within the White Tower? (n/a)

Is the tool easy to use and to navigate through?
Yes, however an introduction of tool would be useful.

Does the tool provide all the information you would be looking for?
Yes, the link, descriptions, and pictures are good.

Does the tool present the information clearly?
Yes

Did you have problems with using the tool?
The green buttons are difficult to see. The "go in" button is confusing and not obvious.

Do you have any improvements to suggest for the tool?
More graphics and more introductory instruction on use would be helpful.

Appendix F – Interview with Bridget Clifford 13 February 2007

What do you believe will be the long-term effect of the archival tool?

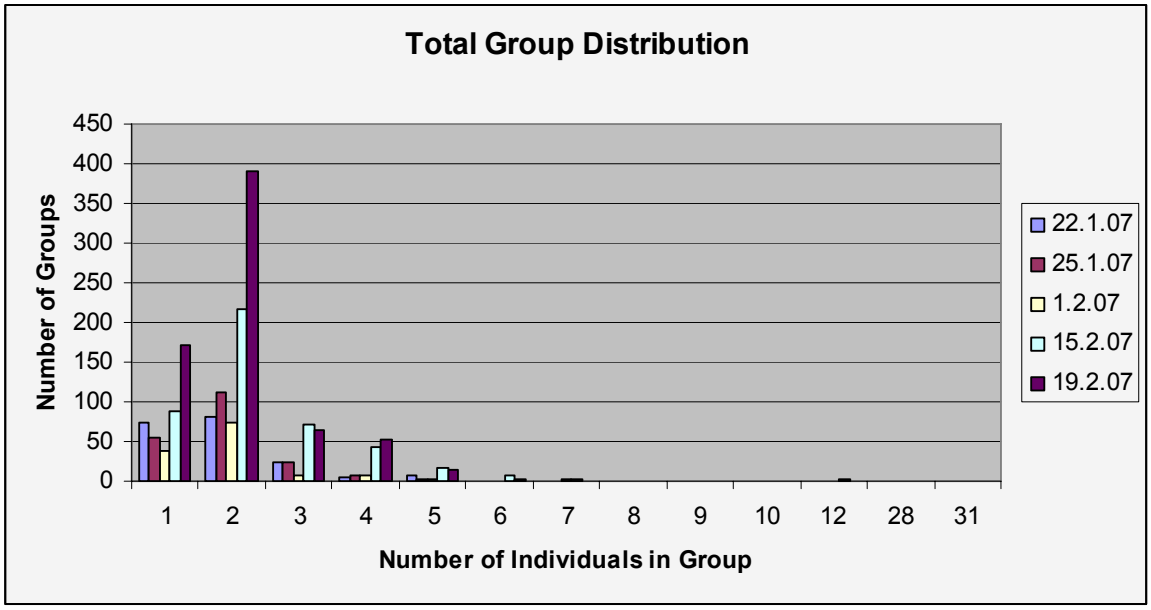
"It drags us into the 21st century." The tool will be a comprehensive tool of possible exhibit changes. It records information on past exhibits from people's little bits of knowledge and from old pictures and documents and combines them into one document. All decent museums keep records of past. The Royal Armouries staff at the Tower of London will encourage other Royal Armouries sites to do the same. Fort Nelson is looking into huge changes and may need an archival tool similar to our tool. A visual tool provides simple, easy, and accessible records of museum contents for various Royal Armouries' staff members.

Concerning education, anything related to museums applies to education. Computer capabilities inspire staff to explore other options and display techniques. It is more useful to have digital archive in "this click-click-click world" rather than previous paper documents. Digital tool is also adaptable to people can easily add information. Different digital applications can be employed. For example as Mandy mentioned putting things in a gallery and having people identify and explore correct options. We can allow people to "play" with ideas. Tool allows staff to reevaluate layout and draw attention to other displays. It is important to make people think about how exhibits are displayed. Museums create own labels and displays, so the "skies the limit in creating different exhibits." Once people have seen something done, like having a new digital archival tool, they will be inspired to continue with the idea.

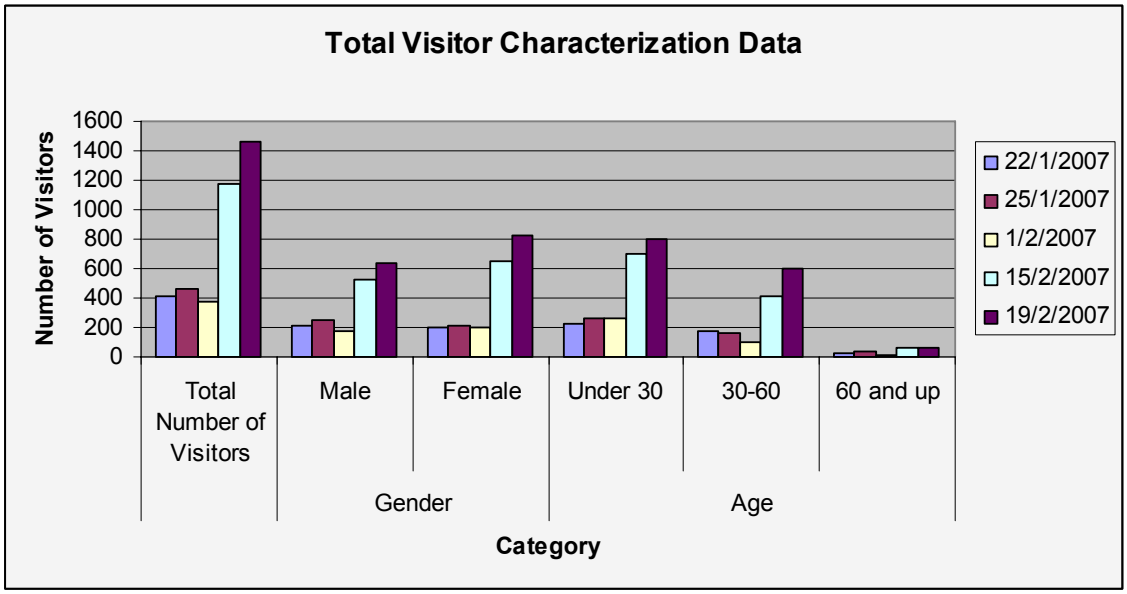
How will the tool affect education at the Tower?

Museums should allow accessibility to informal education. Showing exciting objects to visitors triggers interest so they will "become detectives." "Tempts people into education when they least expect it." "People don't like to show ignorance which makes an educational barrier." Museums do not want to intimidate visitors with labels. Archival tool allows for many evaluations of displays and labels so staff can make best adjustments for least intimidation. People do not want to ask questions, so using the tool to find different methods of communication is important to comfortable education. Adults with interests in museum will be inspired to communicate if museum has new methods of communication. A major weakness will be funding of new technology, however imagination can maximize or limit effectiveness of funding.

Appendix G - Total Group Distribution



Appendix H – Total Visitor Characterization Data



Appendix I – Museum of London Interview

Interview Questions **Museum of London**

Archival Methods:

1.) What type of archival method is used at your museum?

If digital, what types of programs are used?

Staff members number standard size boxes of artifacts with three-letter code for location and two-number code for year (along with more specific coding numbers). Filed cards document these codes as an index. The facility contains three main storage rooms: not humidified (metals), humidified (paper), ambient.
Digital archive is by an American program called Multimymsi.

2.) What information does the archive record?

Does staff record photographs and labels?

Information recorded include year, location where found, etc. Digital photographs of some artifacts exist. Staff members document other, more fragile, artifact with digital x-rays. Line drawings document of some artifacts. Staff members currently work on minimum standards; bringing artifacts up to date, entering onto large database with descriptions and photographs.

3.) How does staff enter new acquisitions into the record?

Can anyone enter in new records? Is it user-friendly? What aspects are difficult to understand?

Staff place new acquisitions in boxes with numbers, and enter new artifacts into the digital archive. Older artifacts are still in phase of data-entry. Eight staff members work at archive.

4.) How do staff catalogue displayed and non-displayed artifacts? **(n/a)**

5.) Are the collections available for loan?

How do you record loans?

Students, researchers, and other visitors can view artifacts at archive. Need to sign in and get visitor pass.

6.) What kind of exhibits layout does the museum commonly display? (e.g. interactive, visual displays, auditory, sensory)

How does staff record this in the digital tool? **(n/a)**

7.) How long have you used this tool?

Museum staff used UNIX until 1995. Can stream data from UNIX to Excel database for use today. Commercial products used now are Oracle (archiving management system) and Multimymsi (archiving tool for museums)

8.) Why did you feel you needed this tool?

The tool allows for accessible learning for research, leadership, and rebuilding life. Impacts society by:

- **Having data close to hand**
- **Not needing to do all own research (a.k.a. not repeating research already done)**
- **Socioeconomic impact by helping people train for jobs through Archival Foundation Volunteer Learning program**
- **Looking at differences of past and present and realizing that the environment is special, different and unique (helps people to appreciate and want to care more about world/environment)**

9.) Did the museum IT department or a software company design the digital tool? What software company is responsible for creating the software of the tool?
What programming language was the digital tools' software written in? (e.g. Java, C/C++, Flash, Unknown)
Tool designed by American company.

10.) What type of interaction do visitors have with the digital tool? (e.g. mouse, keyboard, touch screen, verbal, other)
Is the archive open to the public for online access/viewing?
Do visitor commonly use your digital tool?
Yes, the digital program is open to the public.

11.) Which aspects of your digital tool do you find most beneficial and why?
Which aspects do you find least beneficial and why?
How has your archival method benefited or otherwise affected the museum?
Least beneficial aspect is that the tool only accounts for objects separately, staff cannot group object in tool even though the archive groups artifacts.

12.) Do you analyze visitor flow?
If so, how does the staff accomplish analysis? Does wayfinding affect visitor flow? **(n/a)**
13.) By what means do you get visitor feedback? (e.g. surveys, focus groups) **(n/a)**

Further Research:
Archaeological Archival Forum (AAF)
Counsel for British Archaeology

Appendix J – Wallace Collection

Interview Questions **Wallace Collection**

Archival Methods:

1.) What type of archival method is used at your museum?

If digital, what types of programs are used?

There is currently only a typewritten document, which contains all of the artifacts in the collection. The museum is using a program called Museum Plus to archive their papers and artifacts all the data was just recently finished being uploaded into the database.

2.) What information does the archive record?

Does staff record photographs and labels?

The staff members enter data into the archive, which is both photographic and textual (this includes the labels).

3.) How does staff enter new acquisitions into the record?

Can anyone enter in new records? Is it user-friendly? What aspects are difficult to understand?

There are very few new acquisitions but if they are any, staff members compile information into a secondary archive (a few years ago they closed the primary archive). Staff members enter artifact information into the digital database. The program is user-friendly because of the easy data entry.

4.) How do staff catalogue displayed and non-displayed artifacts?

Staff catalogue artifacts in a large index book, which corresponds to their respective catalogue numbers found on the artifact label in the storage/archive room.

5.) Are the collections available for loan?

How do you record loans?

Yes, the staffs weigh documents on a very precise German scale for only in library use. The staffs reweigh artifacts upon return to ensure the safe return of the document as well as to deter any vandalism or theft.

6.) What kind of exhibits layout does the museum commonly display? (e.g. interactive, visual displays, auditory, sensory)

How does staff record this in the digital tool?

Most of the exhibits are visual displays very few other mediums. They do not record this information.

7.) How long have you used this tool?

July 2005

8.) Why did you feel you needed this tool?

There was no previous digitized artifact documentation. Digital archives are also useful for credibility as well as meeting archive standards for the National Museum Archive Association. The staff needs to maintain digitized archives and update the tool as technology advances.

9.) Did the museum IT department or a software company design the digital tool? What software company is responsible for creating the software of the tool?

What programming language was the digital tools' software written in? (e.g. Java, C/C++, Flash, Unknown)

The staff purchased the software from a German company called Zetcom. They do not know what type of programming language the tool is written in.

10.) What type of interaction do visitors have with the digital tool? (e.g. mouse, keyboard, touch screen, verbal, other)

Is the archive open to the public for online access/viewing?

Do visitor commonly use your digital tool?

In the future they will be using eMuseum Plus to create an online portion with limited access. It will be a standard mouse interface so that users can use it.

11.) Which aspects of your digital tool do you find most beneficial and why?

Which aspects do you find least beneficial and why?

How has your archival method benefited or otherwise affected the museum? **(n/a)**

12.) Do you analyze visitor flow?

If so, how does the staff accomplish analysis? Does wayfinding affect visitor flow? **(n/a)**

13.) By what means do you get visitor feedback? (e.g. surveys, focus groups) **(n/a)**

Other Information:

Other museums: British Museum, ChiChester Cathedral, Sussex grid for learning, West Sussex past, Imperial War Museum, Royal Academy.

Other Museum Programs: Calm archiving, Micro museum.

Freedom of Information Act

ISADg

Appendix K – Imperial War Museum Interview

Interview Questions **Imperial War Museum (phone interview)**
Henry Roberts (hroberts@iwm.org.uk) 020 7416 5331

Explanation: The intent of the interview questions is to collect data from other museums regarding their archival methods and virtual museums. Using this information, we will be able to compare their tools to our ideas, as well as incorporating new ideas into our tool if necessary.

Archival Methods:

1.) What type of archival method is used at your museum?
    If digital, what types of programs are used?

Seven different collecting departments acquire and record various types of data into one digital space.

2.) What information is recorded in the archive?
    Are photographs and labels recorded?

In planning archive, need to figure out purpose and audience, then work backwards from there. Archive depends on users needs. Archive creators consider maintenance of digital archive, whether it is a sound or video clip, if the audience needs to contact the video clip directly or just know that it is a video clip.

3.) How are new acquisitions entered into the record?
    Can anyone enter in new records? Is it user-friendly? What aspects are difficult to understand?

Online accessible tools differ from managing acquisition tools in that online the recorded information is at hand, acquisition archiving is more difficult because you cannot physically contact the artifact at the time.

4.) How are displayed and non-displayed artifacts catalogued?

5.) Are the collections available for loan?
    How is this recorded?

6.) What kind of exhibits layout is commonly used at this museum? (Interactive, visual displays, auditory, sensory)
    How is this recorded in the digital tool?

Recording the information depends on different types, for example if it is video, image, or sound. Video involves telecine tool digital restoration while images store text and characters

7.) How long have you used this tool?

8.) Why did you feel you needed this tool?

9.) Was the software for the digital tool designed by the museum IT department or purchased? What software company is responsible for creating the software of the tool? What programming language was the digital tools' software written in? (Java, C/C++, Flash, Unknown)

Adobe Photoshop for Image Processing

10.) What type of interaction do visitors have with the digital tool? (Mouse, keyboard, touch screen, verbal, other)

Is the archive open to the public for online access/viewing?

Do visitor commonly use your digital tool?

Tool is online.

11.) Which aspects of your digital tool do you find most beneficial and why?

Which aspects do you find least beneficial and why?

How has your archival method benefited or otherwise impacted the museum?

12.) Do you analyze visitor flow?

If so, how is this accomplished? How is visitor flow affected by wayfinding?

13.) By what means do you get visitor feedback? (Surveys, focus groups)

Further research:

Digital asset management (version identification, format migration, rights management).

Six other departments may also provide information.

Appendix L – Museum Representative Interview

Explanation: The intent of the interview questions is to collect data from other museums regarding their archival methods and virtual museums. Using this information, we will be able to compare their tools to our ideas, as well as incorporating new ideas into our tool if necessary.

Archival Methods:

1.) What type of archival method is used at your museum?
    If digital, what types of programs are used?
2.) What information is recorded in the archive?
    Are photographs and labels recorded?
3.) How are new acquisitions entered into the record?
    Can anyone enter in new records? Is it user-friendly? What aspects are difficult to understand?
4.) How are displayed and non-displayed artifacts catalogued?
5.) Are the collections available for loan?
    How is this recorded?
6.) What kind of exhibits layout is commonly used at this museum? (Interactive, visual displays, auditory, sensory)
    How is this recorded in the digital tool?
7.) How long have you used this tool?
8.) Why did you feel you needed this tool?

9.) Was the software for the digital tool designed by the museum IT department or purchased? What software company is responsible for creating the software of the tool? What programming language was the digital tools' software written in? (Java, C/C++, Flash, Unknown)

10.) What type of interaction do visitors have with the digital tool? (Mouse, keyboard, touch screen, verbal, other)
    Is the archive open to the public for online access/viewing?
    Do visitor commonly use your digital tool?

11.) Which aspects of your digital tool do you find most beneficial and why?
    Which aspects do you find least beneficial and why?
    How has your archival method benefited or otherwise impacted the museum?

12.) Do you analyze visitor flow?
    If so, how is this accomplished? How is visitor flow affected by wayfinding?
13.) By what means do you get visitor feedback? (Surveys, focus groups)

Virtual Museums:

14.) Does the museum have a virtual museum or virtual exhibit?
15.) How has your archive been incorporated into this virtual display?
16.) Is the virtual museum open for public access?
17.) Is the same information projected through the virtual tour?
18.) Is the museum accessible for disabled individuals? How has the tool helped these individuals to explore the museum?
19.) Is the virtual exhibit tool interactive? In what way?