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INTERACTIVE LEARNING MODULES FOR THE ROYAL ARMOURIES EDUCATION CENTRE

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EXECUTIVE SUMMARY

The Royal Armouries is an international historical organization that has collections on display in four locations: The Royal Armouries Museum in Leeds; Fort Nelson in Hampshire; The Royal Armouries in Louisville, Kentucky, USA; and Her Majesty's Tower of London. In addition to the numerous historical items on display at HM Tower of London, there is a special collection housed at the Education Centre in the Waterloo building which is utilised primarily for handling purposes by school groups. Exposure to the collection is only available to students who can visit the Tower. This inaccessibility has created a gap between the available educational resources the Tower has and the ability of students to take advantage of them. Advancements in technology have directed education into new ventures to not only educate students, but to engage them while doing so. This shift towards interactive learning is an area the Tower education centre embraces.

The main objective of this project was to close this gap, and although the Education centre continually tries to fill this void with various on-site educational programmes, a link between the classroom and the Tower was the missing piece. To bridge this gap, the team produced two interactive learning modules [one for Key Stage 3 (KS3) and one for Key Stage 1 (KS1)] comprised of an interactive game, *Detective's Notebook* and *Teacher's Guide*. These modules utilise the Tower's resources to help teach material science concepts to students *in the classroom*. The two Interactive Learning Modules provide the first link between the Tower of London and the classroom, stressing the U.K. national curriculum to teach students material science concepts. Figure A demonstrates the bridging of the gap between the two educational domains.

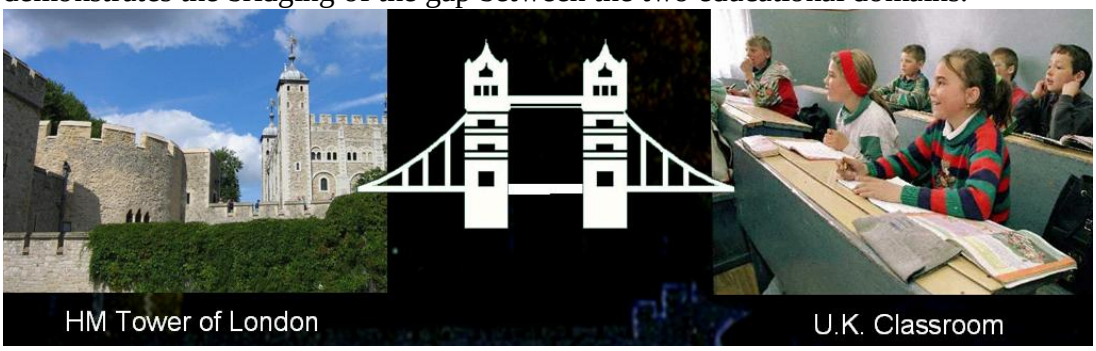

Figure A: Interactive Learning Bridge

Teaching students material science in accordance with the U.K. National Curriculum is the primary focus of the team's liaison, Ms. Mandy Martin-Smith, and consequently was the driving force in the creation of the two learning modules. The team used the U.K. National Curriculum to develop all the questions which appear in the modules and created a matrix, which explicitly shows teachers which aspects of the national curriculum each module and each question addresses.

Students learn much more effectively when they are required to use information given to them to complete a task. Thus, the team chose to convert the learning modules into narrative form. The team adopted a blended learning approach in the presentation of the material science concepts in the modules in order to engage users and help them retain the information. The team titled the module "Mystery at the Tower" and

transformed it from a virtual tour with an overflow of information into a mystery based narrative. To solve the mystery students must answer questions based upon information presented to them previously within the module. When they answer correctly they receive a clue to the mystery. At the end they must decipher which suspect took all the handling objects. As a method of evaluation for teachers the team created a pamphlet containing questions for each object present in the modules as well.

Students in the classroom are intended to use this pamphlet while they are completing the module. The notebook includes all necessary information about the mystery and suspects, as well as additional questions that can be answered from the information in the game. Additionally, teachers can find their own instructional information on the web site, explaining their role in completing the module. This deliverable, known as the *Teacher's Guide*, presents teachers with everything they will need to know in order to successfully utilise the modules.

The inclusion of all of these aspects and considerations produced two learning modules that are comprehensive, informative and enjoyable. The completion of these provided the Education Centre at HM Tower of London with their main deliverables, one that was the first link the Royal Armouries has that attempts to link the Tower education resources with the classroom.

As part of the team's objectives an assessment was conducted to discern the success of the modules. On Friday the 21st of April, the team visited the classroom of Andy Scott on the Isle of Sheppey at St. George's Middle School and were able to observe his KS3 students complete the module. This experience gave the team valuable feedback, and demonstrated the success of the module. The overall impression was that the students enjoyed the game, and were able to complete it successfully. The team gathered data through a student survey that showed that 97% of students enjoyed the game, and an analysis of all collected notebooks showed that 73% of all answers in the notebooks were correct; of the 29 students, 14% demonstrated above average subject knowledge[1]. The KS3 assessment data suggests that the module was effective in both engagement and learning and was instrumental in helping the team to create recommendations for further additions and corrections.

In conclusion, all the products delivered to HM Tower of London and those existing on the Royal Armouries web site provide two comprehensive learning modules. The creation and use of these modules was an initial step in developing a link between museum and classroom education in accordance with the national curriculum. While schools frequently make visits to museums, the education offered by the museum is not always relevant to what any specific year is learning. By establishing a link with the national curriculum, not only will the visit be more educationally valuable, but also the gap between museum and classroom education can be bridged. The modules the team created can serve as examples of how museum resources can be used to provide curriculum specific lessons, and consequently better aid in classroom education.

[1] Above average subject knowledge denotes an answer demonstrating a higher degree of comprehension and expression

ABSTRACT

This report, prepared for the Royal Armouries Education Centre at HM Tower of London, details the design of two interactive learning modules that links the U.K. classroom and the Tower of London without requiring the students to visit the Tower. *The Mystery at the Tower of London* is an educational tool for students to learn material science concepts derived for the U.K. National Curriculum.

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CHAPTER ONE: INTRODUCTION

Museums have long been centres of education in society. Since their first appearance, museums have offered to both show and teach their visitors history, science and art. Traditionally, museums' impact on students relied upon a visit to the museum, but in recent years museums have extended their educational impact through the development of web-based modules and materials for classroom education. As museums do this, the educational goals of relevant national curricula need to be addressed so that the students can receive the education that museums want to teach as well as the education that the government requires students to know.

The process of developing and maintaining effective web-based educational materials is challenging for many museums. Small staffs, ever changing technology, and continually updating curricula make it difficult for museums. One museum that is trying to accomplish this goal is HM Tower of London. As part of the Royal Armouries, the Tower of London is home to the Education Centre that promotes science education through the history of arms and armour. The Education Centre is working to use its resources to bridge the current gap between their museum and the U.K. classroom. At the Education Centre there are many opportunities for students to engage in educational programmes, particularly involving material sciences, which utilise the resources that only the Tower can provide.

The Tower of London has developed a website that provides an *Education* link for visitors to follow from its homepage within the Royal Armouries website. The main goal of the *Education* link is to provide its viewers with the necessary information for teachers to inquire about one of the Education Centre's educational programmes. There are also links within the Tower's website though, that guide visitors through a montage of text-based information and pictures of the Tower. The information is not interactive and does not follow or address any of the U.K. National Curriculum requirements and also requires a trip to the Tower to take advantage of the educational programmes that the Education Centre provides. Moreover, material science education, which the Royal Armouries wishes to promote, was also not included in the website. The Internet is a key domain where the programmes can be promoted to provide classroom materials that address material science requirements from the U.K. National Curriculum.

This project has developed two interactive learning modules that link the classroom learning experience with the learning experience at HM Tower of London as well as addressed requirements from the National Curriculum. The team digitised the collection of handling items and incorporated them into two web-based learning modules in the form of interactive virtual tour mysteries for Key Stage 1 (ages 5-7) and Key Stage 3 (ages 11-14). Acquired material science concepts are tested with questions that will lead to clues to the mystery in order to ensure that material science curriculum requirements are satisfied. Guidelines and a lesson plan for the tour are provided for the teachers online. An assessment was conducted to measure the degree of engagement and learning. In creating this learning environment two goals were obtained: the Royal Armouries education website now exposes students to material science through their handling collection and the first link has been established between the educational experience in the classroom and the unique educational experience at HM Tower of London.

CHAPTER TWO: BACKGROUND

In order to fully understand the problem that the Royal Armouries wishes to address, it was necessary to understand the aspects of education and interactive learning that could play a significant role in possible solutions. Thus, in creating the interactive learning modules, with both KS1 (5-7) and KS3 (11-14) students as major target audiences, the design needed to offer educational opportunities that were properly tailored to the specific key stages in order to be most effective. Undertaking the task to develop interactive learning modules, which involved an educational material science programme, required an understanding of educational theories; the roles museums have in education, and their methods of supplementing classroom education in history, art, and science.

The subsequent sections of this chapter will explore the following:

- HM Tower of London, a brief history
- The Role of the Tower in education and current web resources
- Blending the two major theoretical approaches to education
- Curricular Theories
- The Handling Collection
- Relevant Design Considerations
- Accessibility

What emerged from this background research was a better understanding of educational needs and methods used for different learning styles. Different assessment methods and the success of different learning modules were also obtained. Understanding education and students' educational needs, as well as learning from different modules that have already been implemented helped the team design and implement an effective learning module for the Royal Armouries and HM Tower of London.

2.1 HM Tower of London

The Tower of London was built by William the Conqueror during the Norman invasion after his landing at Pevensey in 1066 using the corner of remaining roman city walls. The white tower is the oldest complete building comprising the Tower of London, and is the reason the castle is called the Tower of London. With the completion of the White Tower in 1078, it was the very first of its kind in England. The White Tower itself received its name from Henry III when he had the tower walls whitewashed in the 1400s. Notorious for being a place of imprisonment, the tower's first notable prisoners were Sir Thomas More and Bishop Fisher of Rochester, both of whom were executed in 1535 for refusing to acknowledge Henry VIII as head of the English Church.

Since the 1700's it has mainly served as a place of storage for arms and armour. Today, all four floors of the tower are open to the public, and contain a series of displays from the collection of royal armouries. These exhibits are mostly used to convey the rich history of the building. As a modern museum, the White Tower education centre, which is run in partnership with Historic Royal Palaces and the Royal Armouries of the U.K., offers a variety of educational programmes to students, such as slide lectures, object handling sessions, art activities and science and technology workshops, in their continuing pursuit to offer educational experiences to key stages 1-3.

Figure 2.1 HM Tower of London

The White Tower museum is also affiliated with the royal armoury in Leeds, which was opened in 1996 for the new national collection of arms and armour, and features five themed galleries: War, tournament, self-defence, hunting and arms and armour.

2.2 The Role of the Tower in Education

The Tower of London has long been a valued and important part of the academic community as a bastion of history and a supplement to classroom education. Exhibits within the Tower are a useful supplement to student's education in multiple subject areas. These exhibits - whether the classic displays behind glass cases with informative texts, or collections of handling objects or interactive exhibits - have been used to inform students and stimulate their imagination and interest in history. One purpose of museums is to teach, which is why they are the common destination of many school field trips. A timely visit to the Tower can not only add significantly to the education of students in a variety of subjects, but might also give them an extra incentive they need by piquing their curiosity and encouraging pursuit of knowledge.

The Royal Armouries Education Centre at the Tower of London provides visiting school groups with an alternative means of learning. Within the educational department are a number of extremely useful tools that provide students with a memorable and enlightening experience. A lecture hall contains the technology to teach students through video and projected material and is also where the Tower's educational members present and instruct the children on the history and science of the pieces. However, for a more hand-on experience the students are taken to the classroom where the handling collection is brought out allowing each student to interact with the various pieces of arms and armour.

It is very important to note though, that the Tower itself does not in general offer educational experiences as comprehensive as those found in the classroom. To complement classroom material, rather than replace it, the Tower education officers have developed various programmes to enhance students' educational development. Their programmes are designed to take the static exhibits and stimulate interest. As Paris and

Hapgood (2002) state in their article *Children Learning with Objects*, "Museum educators know that objects are the starting point, not the ending, of a visitor's museum experience because objects stimulate thought and reflection" (41). That is not to detract from the value of the exhibits, but to understand that children better absorb some information when it can be created into narrative form. The educational officers create an imaginative and exotic environment through exciting programmes.

One such programme is *Science at the Tower*, which offers sessions for KS2 and KS3 students. Current session activities deal with materials and their properties. These include: "Bow and Arrow – which wood?" which is an investigation of the properties of wood designed to have students discover which types of wood would be best for bow materials and arrow materials; "Armour as Evidence" which is an exploration of the materials used in the creation of armour and their differing designs in their relationship to their function; "Murder at the Tower" which is a session that has students use forensic observational techniques, microscopy skills and chromatography and other laboratory skills to solve a real tower murder; "Hard Hats and Heavy Heads" which encourages students to consider the need for protection while observing the properties of various types of body armour.

The general structure of each of these sessions requires the students to visit the education centre. It is here where all the learning takes place, and this is the only access students and classrooms have to these experiences. This framework has been sufficient in the past to satisfy the needs of the Tower, however recently it has been realized that this is not reaching far enough. There is no method for disseminating these internal programmes to exterior schools, which is not sufficient for those schools beyond reasonable field trip distances. Thus, the Tower must bridge this gap and has begun this undertaking.

As part of this current mission, *Science at the Tower* is pushing to create educational programmes tailored specifically to meet the educational needs of KS1 and KS3 students in the subject of material science while also digitising the collection so that it may be available for exploration to the entire nation. Thus, while manipulating museum exhibits to teach material science to target key stages via a digital format, the entire exhibit may be made available to students and adults who are either planning a visit to the museum, or cannot due to physical disability.

The educational benefits of a museum like the Tower differ from that of the classroom because the Tower curator and education officers are much more knowledgeable about the collection and related topics than the average classroom teacher. A classroom teacher is required to have such a broad scope of knowledge in a variety of academic subjects that their knowledge may consequently only scratch the surface of a particular subject area. This is where the Education Centre becomes a valuable resource to students by providing effective amounts of hands on, stimulating, and entertaining learning experiences.

2.2.1 Current Royal Armouries Website

The content of the Tower's educational link at the beginning of this project was not very substantial. The Royal Armouries website can be found at http://www.royalarmouries.org. The links provide simplistic text and picture based

historical descriptions of the Tower. There is also a section describing the programmes offered for students at the Tower, but nothing for them to digest immediately. The web page is basically an advertisement, which cannot bring the Tower to those that cannot visit. It also provides no means of connecting the education in the classroom with that at the Tower. The team was an initialising part of this reform.

Knowledge of the Royal Armouries website and network was required to assess exactly what was feasible in terms of what the network could handle, what platforms and languages were compatible, and what resources were available to the team in its design. The team met with Stuart Carrington from the IT department in the Leeds Royal Armoury to discuss this issue. Mr. Carrington informed the team that the network had such a large space for information available that the actual size of the project would not be an issue. He also introduced the team to the set of templates which the website is based upon. Each template is designed with the Royal Armouries heading and several navigation menus. The templates are all written in Java script, but this did not present any problems, as special templates were created to embed HTML, Flash, audio, and video files. Using the templates, the team could create photo gallery pages, Flash-loading pages, HTML pages, pages with mixed graphics and text, etc.

2.3 Blending the Two Major Theoretical Approaches to Education

The evolution of the Internet has lead to significant changes in educational teaching techniques and methodologies. While many modern museums continue to follow the traditional system of providing visitors with the displays of timeless artefacts, many are now using websites, especially those containing separate student sections. This interactivity allows students to dive into the material and learn without visiting the museum. Several museum sites now contain separate student sections, where interactive games are a way to explain what is to be learned. They also have different guides for different knowledge levels, called Key Stages. An important idea is the inclusion of downloadable teaching guides that educators can use to devise a class plan and instruct students through the web sites. In particular, the “Show Me” website was very comprehensive and includes many different museums (www.show.me.uk). The site is geared towards children of all ages and aims to teach children many different aspects of the world, from space to art. Featuring its own link for teachers, the “Show Me” site is aimed at KS1 and KS2 and provides classroom resources to help teachers make the most effective lesson plan.

Web-based education allows for students to act more independently while developing skills through interactivity. However, while they may benefit by developing skills accumulated on their own, they would be at a loss by not experiencing the face-to-face practice within the classical education scenario. In (Aggarwal 2003) the authors developed a system that combined the technique of “eLearning” with classical education. Their “blended learning” provides students with the benefits of each system, thus allowing for students to develop both on an independent level, as well through the student-teacher relationship. The system, WeBCEIS (Web-based and Classical Education Integration Scenario), provides business students with the ability to obtain knowledge through the advantages of web-learning while still being taught the material which could

only be understood within the traditional scenario. The comparison of the two different techniques that WeBCEIS utilises can be seen in Figure 2.1.

	Classical education	Web-based education	WeBCEIS
Organization			
Knowledge Supply	development of presentation material and script	development of Web-based material	development / tailoring of - presentation material - Web-based material
Knowledge Transfer	lecture	Web-based material, video conferencing	lecture + Web-based material, video conferencing
Knowledge Acquisition	seminar, laboratory courses	teleseminar, Web-based tutoring	seminar + teleseminar, laboratory courses + Web-based tutoring
Knowledge Control	classical examination	Web-based examination, Web-based self-assessment	classical examination, Web-based self-assessment
Administrative affairs	paper-based	Web-based	Web-based
Social affairs	face-to-face communication	Web-based communication	face-to-face communication supprted by Web-based communication
Technique	blackboard, chalk, overhead projector	network, teleclassroom, browser, authoring tool	blackboard, chalk, overhead projector, network, teleclassroom, browser, authoring tool

Figure 2.2 Classical vs. web-based learning (Aggarwal 2003).

While both techniques are effective on their own, merging the two can develop students in areas that could not have been obtained independently. Students have all of the benefits of the traditional scenario featuring face-to-face instruction while still developing independently and receiving interactivity through eLearning.

Although detailed, a system similar to WeBCEIS would enable future visitors to the Tower of London handling collection to have the proper background regarding the exhibit that would translate into an extremely productive experience. Preparing the students through a digitized collection would allow them to appreciate the collection by understanding the science and history associated with the objects. The project did not simply revolve around the principle of providing students with pictures and allowing them to identify the objects once arriving at Tower. Rather, the focus was to prepare students for greater comprehension of the history and science that is tied to the handling collection. A "blended learning" system, which provides students with both the advantages of interactive web-based learning along with the classical education scenario, would prepare students in a more comprehensive manor. This was the approach taken by the team: to create a tool that incorporated both aspects of learning.

In order to offer an effective educational experience that students could take with them after experiencing the learning module of the exhibit, the concept of education had to first be researched. More specifically, the main different educational methodologies had to be explored and reviewed, in order to decide which methodology would best accomplish the goals of this project[2]. Traditionally, there have been two major views on

[2] For more detail refer to Appendix B.

the best possible way to provide students with a quality education, and it so happens that these two methodologies are somewhat antagonistic in nature; these methodologies being the *traditional* and new age *progressive* approaches.

Today the solution is seen more clearly: that the progressive educational approach is the perfect supplement to the traditional didactic educational methods. Classroom learning seems best when conducted with structure and under the authority of teachers due to the large number of children and their tendency to neglect learning the subject material if given the chance. Thus, due to the inherent potential of the traditional methods to come across as droll and uninteresting (and even tyrannical), progressive methods such as laboratories, projects, field trips and interactive activities can supplement classroom learning by presenting students with more academic freedom, stimulating excitement and giving them more practical and hands on experience with the subject material.

The Tower's educational programme focuses on science and history that is expressed through the objects within the collection and utilises a progressive approach. Although some teaching is accomplished through the face-to-face scenario, the hands-on and interactive instruction is much more popular and proves to be very effective. The team used a similar approach in designing the interactive learning module, utilizing progressive methods in combination with some traditional techniques.

2.4 Curricular Theories

A vital aspect of the learning module was the integration of the U.K. curriculum into the design. To successfully do this the team considered several theories on the best methods for capturing students' attentions and successfully teaching them. Lindauer addresses this issue of combining and integrating curriculum (Lindauer 2005). One concern is that a curriculum naturally refers to a broad yet structured experience. The goal of the Royal Armouries Education Centre at the Tower of London is to incorporate national curricula into their museum mission and improve the handling collection through the use of science and history at the Tower of London.

In order to demonstrate the different curricular theories for learning, Lindauer uses the Brooklyn Museum as a model. There are four theories: laissez-faire, Tylerian, constructivist, and narrative. It was found that that the constructivist and narrative curricular theories would be most effective when developing the learning module programme.

The constructivist theory is most notably a curriculum method that involves a problem solving approach. The problem solving approach allows the visitor to seek answers to questions or problems. This incentive to seek out answers and construct one's own opinions is a very different learning style than other theories. The role of the educator is to provide questions that provoke thoughtful educational answers and then allow the visitor to explore his or her own answers to those questions. The theory can be evaluated by examining the answers that are arrived upon for each question. This method provides the student with a purpose to actually stimulate their knowledge and learn something new.

The narrative theory is formed on the basis that the visitor will understand more of the information if it is presented in a story. The benefit of presenting knowledge through a story that may or may not be true is an issue that is unsolved. Presenting a story

by itself though is certainly not sufficient to stimulate learning in a visitor. The narrative can act more as an "attention grabber" that will encourage the visitor to explore further, but should not be used alone (Lindauer 2005). The modules created took into consideration mainly these two theories and were designed with a detective mystery to engage the children. The story requires the children to answer questions based upon information they were previously presented in order to proceed. Successful completion forces students to find all the answers on their own while directing them to succeed. Combining a narrative based learning module with questions that build up towards a larger solution will yield successful learning modules.

2.5 Handling Collection

The collection consists of some 100 items of various arms and armour. Access to the handling collection and handling point in the White Tower provided further information that was useful in idea development for the interactive learning module. After going through the objects in the handling collection it was deemed necessary to carry out further research into the material properties as well as the history of the object. Bridget Clifford, the Senior Curator at the Tower of London, provided the required historical information, but it was also necessary to conduct further research, especially in the area of material science in regards to the objects.

2.6 Relevant Design Considerations

In order to develop a competent digitised educational tool for the Tower of London the team needed to observe the important components, strategies, and potential issues from contemporary examples. Almost as soon as computers were developed it was realized that they were a powerful tool for cataloguing collections and making them easier to search through. As early as the 1970's the Natural History Museum in London began to utilise computers to produce inventories for the zoological collection. The International Council of Museums (ICOM) decided in 1989 to make a resolution (Sabin 1997). The essence of this resolution was to convey the need for documentation and cataloguing to disseminate information and safeguard the collections. Additionally, they urged museums to develop databases and work closely with other museums so that information could be shared. One product of this change in mindset is the Micro Gallery, which is part of the National Gallery of London. Richard Sabin analyses this exhibit through his own experience and provides many insightful comments relevant to this project's goal. The Micro Gallery contains digital images of over 6,000 paintings, with background on the artist and other auxiliary information. One criticism of this collection is that the quality expressed on the computer screen diminishes the impact of the art; however the intentions of the system are to enhance the patron's knowledge and make it easier to find what interests them. These intentions and concerns are carried over into the development of the team's digitised collection. In digitising the collection in database form the team has included information about each item as well as an image that effectively displays the historical pieces of arms and amour.

Although the movement towards web technologies has been a boon to educators, there are some pitfalls involved when designing such a system. These pitfalls were addressed when crating the interactive portion of the project. Ben Gammon, the head of

visitor research at the Science Museum in London, provides tips and warnings to those developing educational systems in his paper, "Advice on How to Develop Visitor-friendly Computer Exhibits or Seven Gruelling Years of Watching Angry Visitors." (Gammon 2002) This resource provides many small ideas that are too numerous to list here, but there are a few key points, which are applicable even though the module is designed for classroom use. When designing the layout of the page special attention should be paid to the active areas. These are areas where the user can accomplish something, and they must stand out clearly from the background of the page. The size, placement, and contrast of the active sites will enable visitors to identify and use them properly. Another consideration to the layout is the ability to display effects. If something changes it must stand out and be able to catch the eye of the user. Also multiple actions should be avoided because it is harder to concentrate on two things changing at the same time. Navigation is an important feature as well, because the way in which visitors navigate through different pages is unique to each person. But, a visitor should not have to struggle to navigate due to a lack of proper instructions. The symbols and end result of navigational buttons should be intuitive. Additionally, the presence of help functions is often times useless, because most visitors have previously had bad experiences with other help programmes. Therefore it should be made clear how things work directly on the screen (Gammon 2002). These were all important areas that were considered during completion and implementation of the team's design.

In addition it is important to be able to analyse the success and effectiveness of a given exhibit through the use of an educational framework. Devising such a framework was the goal of Eshaa M. Alkhalifa and Fawzi Albalooshi when they developed a three dimensional approach for the evaluation of educational software (Albalooshi, Fawzi 2003). The three parts of their evaluation are the systems architecture, educational impact and affective measures. The first is used to gage the overall ease of use and design. This can be accomplished many ways and is not limited to simple surveys. Secondly the educational impact must be assessed, which is usually accomplished through pre and posttests. Finally there must be an avenue for open feedback without bias. These three aspects have been used as guidelines when examining our module. Through the inclusion of open-ended question in the design, along with a gradable notebook gives an idea of the educational impact along with the trial at an elementary school. The observation of children using the module in a classroom setting allowed the team to judge all three of these aspects which allowed for the evaluation of the product to discern which methods or attributes were desirable and which were superfluous.

2.7 Accessibility of Museum, Library and Archive Websites

To create an equal and all encompassing environment the Tower must compile with all current laws. An extension of this is the development of web resources that are also compliant. The Discrimination and Disabilities Act of 1995 introduced an updated view upon necessary accessibility accommodations, in particular the accessibility of museum, library, and archived websites. The MLA audit conducted by City University in 2004 provides key findings and constructive recommendations that all websites should take into consideration when developing a web-based learning tool. Per request of the Education Centre an emphasis has been put on accessibility, as thus this information will

be used in order to develop an accessible learning module that the team will deliver for the Tower of London. The team worked closely with Liz Denton to ensure that the following W3 requirements were satisfied.

2.7.1 Issues Related to Presentation of Content

One item that must be addressed when developing web-based learning modules is the physical presentation of the content. As the team develops and revises its web-based information it is important to consider the presentation design. Colour and contrast schemes are both aspects of web-based designs that play a pivotal role in the designs effectiveness. Pale text on pale backgrounds is often a common mistake among web designs. It also noted that even though contrasts are viewed as effective some contrasts are said to be too "glaring" (i.e. yellow text on a black background). It is noted that using darker text on a lighter background is much more effective. Another issue that many users have among many websites is that the text sizes are often too small. Allowing users to be able to re-size the window and increase the text size is often a recommendation by persons with disabilities. The study emphasizes that colours alone should not be used to convey distinctions and high contrasts between colours should be implemented. The use of images and new media is also a problem area in many websites. It is now a requirement that all non-text based items need to have informative text attributed to them. Designers should also take into consideration that collections of objects should be described in a way so that persons with vision impairments may be able to understand what it is that is being presented. Even audio information should be supplemented by text as well.

2.7.2 Issues Related to Navigation and Orientation

In order for the website to be user friendly it is necessary to use informative links. It was found that several times websites had links that led to unexpected information. This lack of navigation often times discourages users from using the website. Implementing a navigation tool bar that is consistent throughout the entire website is the key to keeping the website effective and user friendly. Unfortunately this navigation bar often times hinders persons with severe visual impairments. It has also been found that JAWS is the most common screen-reading software. This software can recognize navigation bars and avoids reading them repetitively. Sadly, for those who do not have JAWS there needs to be a way to view the website without the navigation bar so that it is read to them each time a link is followed. This requires that the team could set-up two different sites that would allow users to access just the main content of the particular website. Inadequate web page designs cause many problems for those persons with disabilities. The team will look to alleviate these problems in the development of the web-based module.

In the process of designing the web-based module, the team will abide by all of these recommendations, as they are all compliant with the Web Accessibility Initiative (WAI) and the Web Content Accessibility Guidelines (WCAG). Each of these was established so that the needs of those persons with disabilities would be satisfied in regards to web accessibility.

CHAPTER THREE: METHODOLOGY

The focus of this project was to assist the Royal Armouries with their science education programme by enhancing students' understanding of lessons regarding material science. The team developed suggestions for the science education programme and implemented those suggestions with the necessary approval from the education centre.

The team was on-site to complete the project from March 13, 2006 through April 28, 2006. As a result of the proposal, the implementation of the methods and suggestions outlined in it were initiated upon the team's arrival. In conjunction with support from Mandy Martin-Smith, the Science Education Officer of the Tower of London, the team was able to provide a means disseminating lessons from the handling exhibit at the Tower through interactive learning modules.

In order to satisfy the goals of this project there were several key objectives that had to be addressed. Figure 3.1 illustrates the approach that was taken to solve the problem.

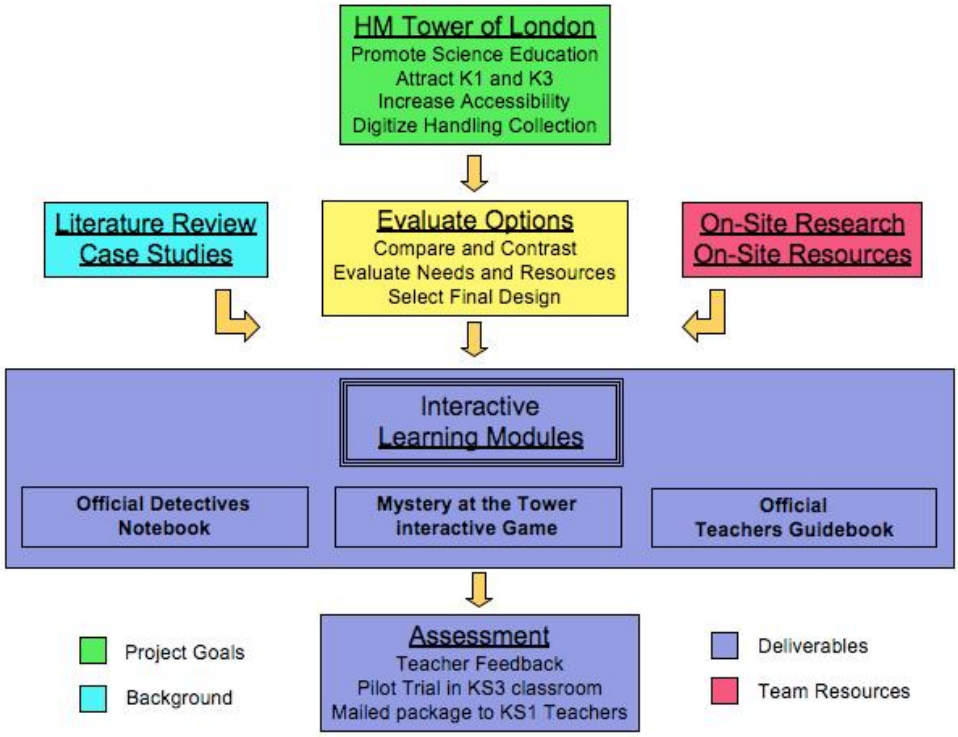

Figure 3.1 Methodology flowchart.

Following the approach from the methodology flowchart, the team completed the following tasks as a means of successfully solving the problem at the Tower of London:

1. Digitise the handling collection
2. Design and implement a prototype learning module based on the blended learning system
3. Design methods of assessing the effectiveness of the module

3.1 Digitise the Handling Collection

A preliminary goal of this project was to digitise the collection of handling objects. The team converted all of the handling objects into digital images within the first three days on-site. The pictures were taken against a uniform background, so that they could then be edited using Adobe Photoshop to create a uniform format. A Kodak DX6490 4.1MP, 10X optical zoom camera, made in Rochester, NY was utilised for this task. The collection was then formatted into a comprehensive database using Microsoft Access. This database includes the following fields:

- Item name
- Item description
- Identification number
- Picture

The table form was then made into a report form database. This created search fields and allows for easy viewing with out allowing the information to be changed. The database is a tool that can be utilised by the Tower education team to design more comprehensive activities. By having the ability to search the database for specific information items they can be combined and utilised in new ways, to demonstrate new ideas.

3.2 Learning Modules

The main product of this project was the development and implementation of the learning modules for KS1 and KS3 students. In total there are two learning modules: one for KS3 students and one for KS1 students, which included age relevant material in an interactive game. These two modules cover the entire spectrum of target students, while providing a resource for students of all ages who wish to get a feel for what the Tower has to offer. The modules are comprised of three main parts: the interactive game, *Teacher's Guide* and *Detective's Notebook*. Each of these deliverables was created using different technical methods, and satisfied different aspects of the team's educational goals.

3.2.1 Interactive Game

The varying interests and educational abilities of the different age groups require the development of similar interactive modules with different content. Since KS3 students are older (11-14 years of age), their module includes more detailed information than the KS1 (5-7 years of age) module. These both address the other major concern of the Tower of London: to expand the accessibility of the Tower of London to audiences who are not physically able to actually travel to the site. Therefore, through the development of the interactive virtual tour, even those who cannot see the objects in person can still appreciate the history and science within the exhibit.

The composition of the modules includes a walk-through of the White Tower combining short videos with still images. Visitors are able to continue their trip throughout the exhibit until they experience the entire collection. The handling collection is highlighted in the still pictures and leads to the display of the material science properties. The observation and collection of these items has been incorporated into a mystery narrative to encourage completion and add to the reinforcement of the information.

The modules designed for HM Tower of London integrated all the movies, picture, and objects through Macromedia Flash Professional 8. This programme allowed for the creation of an easily navigable interface linking all the features. This produced a single file that was then embedded into the Royal Armouries web site and made public upon completion. During the development several important features were paid special attention. These are summarised in Figure 3.3, the completed checklist. During the term there were several main steps taken to complete the modules:

- Collection of Digital images and movies of the White Tower
- Acquisition and learning Macromedia Flash
- Colleting all graphics and Icon images
- Designing Interface
- Development of Text
- Collection of Audio
- Integrating Materials
- Testing

Important Design Characteristics Checklist		
Idea	Purpose	Included
Active areas stand out and are easily distinguishable from background	Allows user to clearly identify useful areas	✓
Distinguishable display effects: must stand out and draw attention	To convey change to the user	✓
Navigation: clearly defined and easy to master	For ease of use and successful exploration	✓
Inclusion of all relevant instructions	Allows user to learn system without a help function	✓
Limit to text: 30 to 100 words per screen, no scroll bar, place overflow text on separate screen	Users do not like to read text on computer screen so it must be split up and easily digestible or they will skip it	✓

Figure 3.3 Important design characteristics checklist.

The first of these tasks undertaken, the collecting of all the images for the tour, was completed during the second week on-site. The pictures and movies were taken over the course of the week (during business hours) creating a complete walk through of the White Tower proceeding from entrance to gift shop. The path of the tour was dictated by the organized flow through the Tower that has been established, and which most visitors follow. The same camera used for digitising the handling collection was utilised for these images and movies. The movies were taken without the use of any special equipment, which provides a more realistic walking motion. Once all the images were collected, they were sequenced and edited. The goal was to produce movies that ended with a frame similar to the next still picture so as not to confuse anyone unfamiliar with the layout of the site. The movies were also edited to remove the sound and unwanted frames using iMovie HD on an Apple iBook G4 computer. Once these multimedia files were compiled the process of integrating them into an interactive format was undertaken.

Macromedia Flash Professional 8 is a programme that allows for the integration of pictures, movies and sound in a format that can handle external input. Therefore the tour could be created with a simple interface for navigation and active buttons for more information. Once this programme was acquired it was learned through the completion of the provided tutorials. The team had no previous knowledge about the use of Flash, so this was a major deficiency that was remedied by completion of the tutorials. Once the basic knowledge was gathered the module could be started. The first step was to create the basic interface and background that would be seen throughout the tour. This included a title, forward and backwards navigational arrows, and a boarder. The sequenced pictures were then introduced producing the first version of the completed walk-through, containing no information. The selected handling items were then inserted as buttons that opened informational windows. Once these were created, the mystery took shape through the inclusion of the magnifying glass to indicate clues. The clues prompt the students to answer questions based upon previously presented information in order to receive information on the culprit. The information and suspects included were derived from the key stage relevant information developed by the team. The final design for the KS3 module also includes an interactive map, allowing users to quickly jump to a desired location.

This basic framework was modified for both key stages. The Key Stage 3 module includes, along with the material science information, information about each room within the White Tower. These were taken form a booklet produced by the royal armouries called “Tower of London: A Brief History and Guide for Teachers”. These simple room descriptions add a bit of extra information, mainly for those using the module as a replacement for visiting. This is in the form of a simple description of what the room contains. The KS3 module also includes a dictionary button, which opens a separate window of terms for easy reference. To incorporate work completed by the WPI team from last year, a portion of their project is contained as a link in the game. This is a periodic table that is also created in Flash, and provides the students with an additional resource.

The KS1 module has unique features as well. It includes a recording of each slide as read by Bridget Clifford, as well as character slides read by other members of the education centre. The audio was included to assist those students who have difficulty reading, and allow them to keep up with the rest of the class. The team also created a heraldic shield maker as a supplement to the mystery, in which KS1 and KS3 students can produce a shield with the heraldry of their desire. This is intended be printed for the students with their surname. This addition was also designed using Macromedia Flash 8 Professional. The heraldic shield programme is in accordance with the U.K. Literacy and Design and Technology requirements. All these incorporated features were derived from material developed by the team. As described Section 2.3 the blended learning model is a key aspect in the tour and includes a system, which combines the two techniques towards teaching while remaining captivating to the children. The modules are much more than a simple trip through the Tower; there is an engaging mystery to be solved.

3.2.2 Detectives Notebook

The content of the module includes the handling objects, material science, room descriptions, and mystery game. As an interesting and engaging way to tie these things together the team created the *Official Detective's Notebook*. The team, through research and discussion, created each of these aspects with the education officers. Eight items from the handling collection were selected and their pictures were used as the interactive buttons. These items were used as a vehicle to convey the material science desired. The team wrote the information incorporated in the tour after research relevant to the curriculum. This material science information draws comparisons between the handling objects and modern examples as well as some history. To aid in the completion of the modules the students must complete the *Official Detective's Notebook* appropriate for their key stage. The notebook includes a mission statement, instructions, information about the suspects, and relevant questions about the items.

"A Strange event has occurred within the walls of Her Majesty's Tower of London. Someone has taken several historic objects of the handling collection…" This is the beginning of the *Official Detective's Notebook* developed for the module. This notebook incorporates the narrative theory discussed in Chapter Two Section 2.4. The story is used as a method of engaging students in the module and helping to reinforce the information presented. Students must travel through the Tower gathering the items and learning about them. The information the students are presented with is dependant upon their key stage. Each key stage notebook includes three suspects that may have committed the crime. Throughout the tour students must answer questions based on information they were given. When they give the correct answer they are given a clue to help them solve the mystery. Within the notebooks there are questions and places for the students to record messages as they travel through the interactive game. These questions are based upon the guidelines for material science found in the U.K. curriculum. Once having selected the items within the game, the students will be able to discover the answers and complete the notebook and their mission.

The game and *Detective's Notebook* are products that will be completed by students within the classroom. Children will work independently within the programme but will be able to receive assistance from their instructors. Therefore, the children will be able to learn through both of the educational scenarios the team had researched. This link will also contain the notebooks for printing and distribution.

The combination of the traditional educational scenario featuring the teacher-student relationship, with the new age web-based learning as described in Chapter Two Section 2.3, can provide the students with the optimal educational experience. With much of the information for the younger children revolving around knowledge that would be acquired by the senses, teacher assisted learning would be quite beneficial.

3.2.3 Teacher's Guide

The third deliverable of the modules is the *Teacher's Guide*. This document contains all of the instructions and materials, which teachers must understand to ensure that the module is properly run. All of the materials were designed in a linear fashion in order to ensure that teachers completely understand all of the necessary information. The guide begins with a "Letter to Teachers" which provides teachers with the multiple

features within the web-based learning programmes. This letter was designed to highlight the educational element within the programme. Teachers will immediately understand that education was the essential concern for the team throughout the design of the module. Following this, teachers will come across instructional pages, which explicitly describe both the module and the heraldic shield programme. Teachers are then given a letter, which they are instructed to read to their students to introduce the *Mystery at the Tower of London*. The second half of the guide revolves around the educational elements within the programmes.

Following the "Letter to Students", the guide contains an outline of the U.K. curriculum. This curriculum contains highlighted parts in order to show teachers which sections are satisfied through the interactive programme. From this, teachers will understand which aspect of the science curriculum can be found within the module. An even more important aspect to the guides is a comprehensive matrix, which provides teachers with the details revolving around the education within the programme. This matrix, shown in chapter four, explicitly shows which part of the game and *Detective's Notebook* relates to which curriculum goal. The completion of this matrix was done utilising Excel, and provides a tangible description for teachers as to why their students can benefit from the module. The final piece of the guide is the material science information, which their students will come across within the programme. Teachers will be able to view the information within the module without having to actually travel through the module themselves. Although the team recommends that teachers experience the module themselves, the guide provides another resource for teachers to utilise and better understand the module.

The overall outline of the *Teacher's Guide* is to provide explicit instructions for teachers while stressing the educational elements within the programme. Throughout the design and completion of the module, the U.K. curriculum was always the major concern of the team. Therefore, the guide was designed to emphasise the knowledge, which students will take away from the interactive experience.

3.3 Assessment

This assessment determined whether or not the module was engaging an educational, and to what degree of success. In order to properly assess the effects of the product the team use the three-dimensional approach described in Section 2.3. There were three forms of assessment that the team used:

- Demonstration to KS2-5 teachers
- Pilot test in KS3 classroom
- Package mailed to KS1 students

These methods discussed below provided the team with information for refinement, and conclusions, which are included in chapter five.

3.3.1 Demonstration to KS2-5 Teachers

The input of KS3-5 teachers was collected on Friday the 7th following a short demonstration by the team. Teachers were presented the KS3 tour and shown the

notebook, and their responses to verbal questions were gathered. These responses gave the team an initial analysis of the module and are summarised in chapter four. The process for collecting teacher responses was very informal as they were taken during a short coffee break as part of a larger programme. The team set up a demonstration and answered questions for teachers who were self motivated to investigate the module.

3.3.2 Pilot test in KS3 classroom

The visit on Friday the 21st of April to the classroom of Andy Scott at the St. George's Middle School allowed the team to observe 29 Key Stage 3 students completing the game, and filling out the *Detective's Notebook*. The team was present during the entire duration of the test, and was able to gain unstructured feedback from students' questions and overall attitudes. A short survey, included as Appendix C, was conducted after completion. The survey questions were composed in an attempt to extract information from the students regarding the key three aspects. This allowed the students to grade the game in several key areas on a one-to-six scale. The measure of success for the team was an eighty-percent approval rating of the design of the game, the ability to use the interface, and the enjoyment. The results from these surveys are summarised in chapter four, and conclusions are drawn in chapter five. In addition to the students direct responses the team analysed their completed *Detective's Notebooks* for completion and correctness. This provided the team with an assessment of the educational impact of the module in an objective manor. Another product of the visit was the feedback from Andy Scott, the teacher of a year seven class. His completion of a similar survey is included as Appendix H, and led to important conclusions presented in chapter five.

3.3.3 Package Mailed to KS1 Teachers

In addition to these tests the team sent CD copies of the KS1 module including the *Detective's Notebook* and teachers guide to eight KS1 teachers. These teachers were chosen by the team's liaison due to her previous employment as a teacher in the same area. This dissemination was an attempt to have the teachers try the module and provide feedback. These copies provided another set of feedback included in chapter four, though not as extensive as the other two forms. They also provided the team with ideas for further recommendations that were beyond the scope of this project and are included in chapter five.

CHAPTER FOUR: RESULTS AND ANALYSIS

The main result of this project was two complete interactive learning modules. These interactive learning modules provide students of KS1 and KS3 with a very unique learning experience. The modules are the first to provide students with a learning experience without requiring a trip to HM Tower of London. In order to construct the complete learning programme each of the following products were developed:

- Handling Collection Database
- Key Stage 3 Learning Module
    - *Mystery at the Tower of London*
    - *Teacher's Guide*
    - *Official Detective's Notebook*
- Key Stage 1 Learning Module
    - *Mystery at the Tower of London*
    - *Teacher's Guide*
    - *Official Detective's Notebook*
    - *Heraldic Shield Maker*
- U.K. Teachers' Assessment
- U.K. Students' Assessment
    - Key Stage 3

Each of these deliverables was essential in the completion of the learning modules and will be elucidated further in the subsequent sections.

4.1 Handling Collection Database

Upon arrival to the Tower of London the team digitised the handling collection into a database as the first step toward the completion of the learning modules. This database proved to be beneficial for the Royal Armouries as well because now all of the documentation and information for each item is stored in a single report that can be found on the web for all to access. More importantly, the database served as a useful resource tool for the team. By constructing the database first, the team was able to familiarise itself with the entire handling collection. A sample of the database is shown in Figure 4.1.

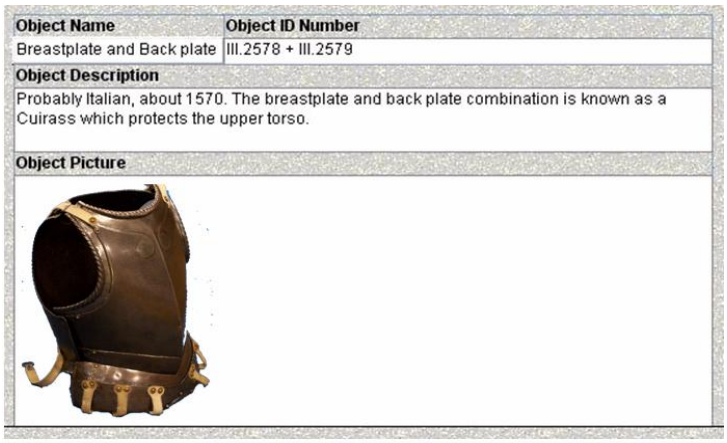

Figure 4.1 Sample of handling collection database.

When searching the database the user can find high quality images of the pieces that will be useful in identifying each item in the handling collection as well. It will serve as a comprehensive catalogue of the collection that can be used by Royal Armouries.

4.2 KS3 Learning Module

The interactive learning modules are the key results of the team's project. The modules consisted of several different parts that are each an intricate part of the entire educational experience. The KS1 and KS3 modules have been divided into two separate sections so that different details of each module can be distinguished.

4.2.1 KS3 Mystery at the Tower of London

The KS3 learning module is displayed in a storyboard format throughout the following section. The mystery requires students to go throughout the White Tower to search for stolen museum items. Significant sections of the module are shown in the following figures.

Figure 4.2 is one of the three instructional slides that a student is presented with once the tour begins. The mission statement provides the student with instructions to follow throughout the rest of the tour. Arrow buttons are provided to allow the user to move forwards and backwards throughout the module.

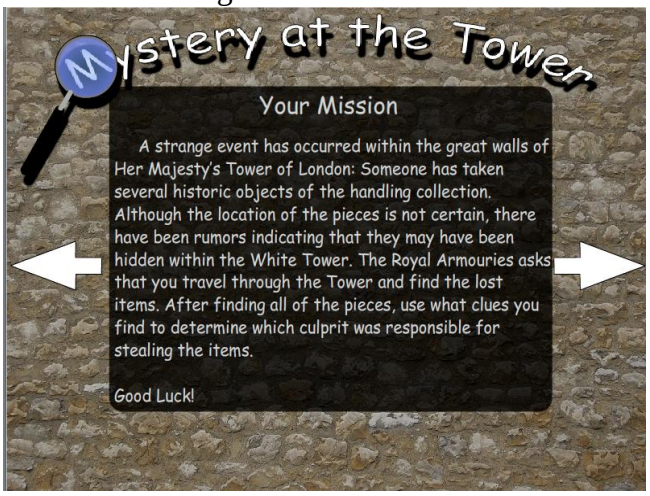

Figure 4.2 KS3 mission frame and interface.

Figure 4.3 is one of the rooms that a student will encounter during the interactive learning module. The interface of the module includes a map button and a dictionary button. The map and dictionary buttons are shown in the subsequent figures.

Figure 4.3 Example of lost object.

The figure below (Figure 4.4) is the map screen that students will encounter. The red dot on the map depicts where the user is in the White Tower. On the left hand side the user is presented with information about what room the user was just in.

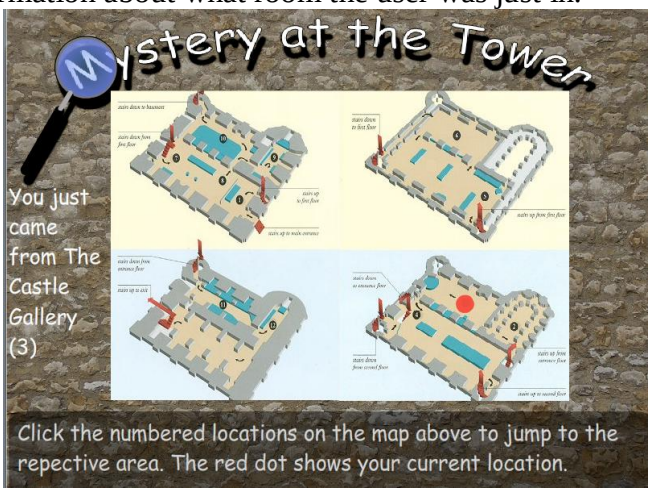

Figure 4.4 Map frame.

Once the student has found a missing item and clicked on it they will see an informational screen as shown in Figure 4.5. The information frame provides the student with material science information related to the object that they have just found. Asterisked and italicised words are links to further information, which are necessary to answer clue and notebook questions correctly.

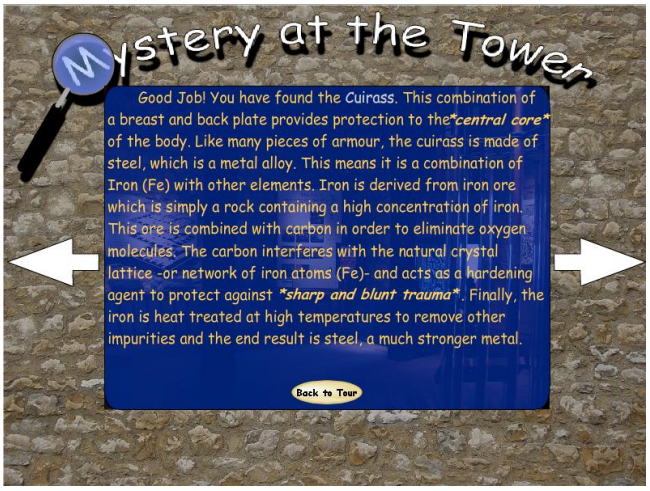

Figure 4.5 KS3 item information frame.

Another aspect of *Mystery at the Tower*, shown in Figure 4.6, is the clue symbol that the students will encounter. The clues will provide questions for students to answer and upon completion the students are presented with information that will lead to discovering the thief.

Figure 4.6 Example of clue symbol.

Following the clue symbol frame (Figure 4.6) the student will be asked a question as shown in the Figure 4.7. These questions are based upon knowledge that the student should have learned previously in the module. The correct answer will provide the student with a clue to the identity of the culprit.

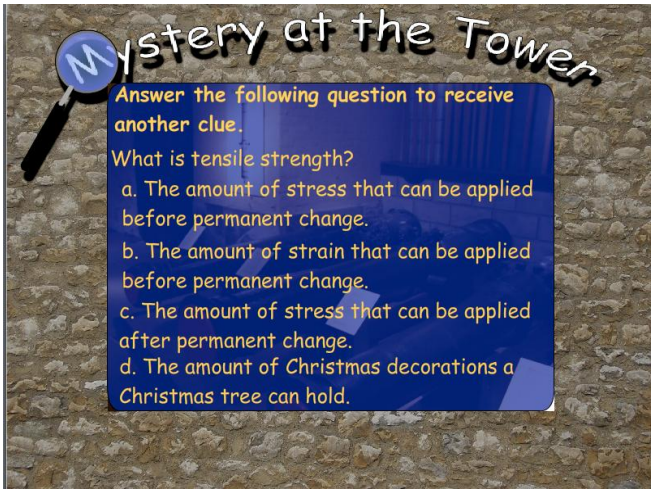

Figure 4.7 KS3 sample clue question.

Figure 4.8 is a sample clue that the student will receive upon selecting the correct answer to the question. There is room for the student to take notes on the clues on the back of their *Official Detective's Notebook*.

Figure 4.8 KS3 sample clue.

This final frame, shown in Figure 4.9, is the ending that the students will encounter in the module. This frame is where the student will be able to use all of the clues that they have collected to accuse one of the suspects of committing the crime. If the students select the wrong suspect they will be sent back to the beginning. If the student students select the right answer the will have successfully completed the learning module.

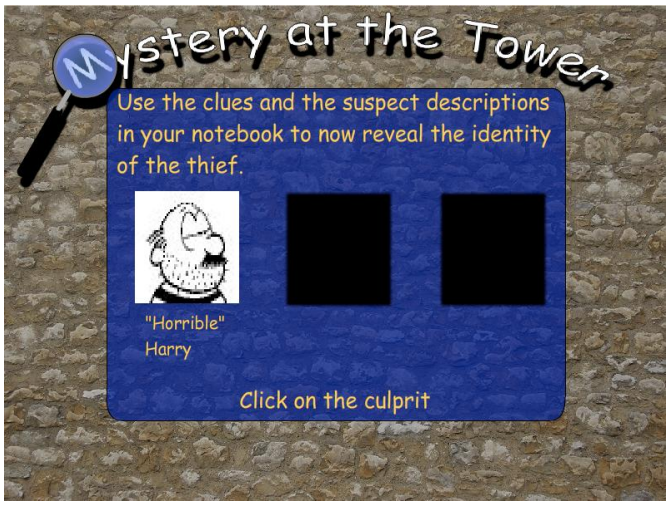

Figure 4.9 KS3 accusing the suspect frame.

4.2.2 Teacher Materials

When a teacher accesses the Royal Armouries website and follows the link for the *Mystery at the Tower of London* they will find a downloadable version of the *Teacher's Guide*, included in this report in Appendix E. Inside the guide the teachers are presented with all of the information that will be necessary to implement this module in a classroom lesson. The teacher's first instructions are as follows:

> *Dear Teacher,*
>
> *The following web-based learning module has been developed in order to enhance students' knowledge and understanding of material science and at the same time expose the students to the White Tower at HM Tower of London. The Royal Armouries in cooperation with the Worcester Polytechnic Institute have ensured that this learning module addresses several of requirements of the U.K. National Curriculum. The parts of the U.K. curriculum, which the module targets, are highlighted in later sections.*
>
> *This guide also contains the material science information, which your students will encounter within the module. The underlined/asterisked words are those, which are active links within the module and provide students with more information. There are also buttons in the programme, which are labelled "more" to present additional material. The guide follows a very similar format as is seen within the programme.*
>
> *Aside from the interactive learning module, another educational programme for students is a "design your own heraldic shield." The instructions for this programme can be found in a later section.*
>
> *Please continue and read the instructions listed below.*
>
> *Thank you.*

This provides a background for the teachers as well as directing them towards the curriculum guidelines that will be satisfied when a student completes the *Mystery at the Tower*. The instructions for the entire module are also provided in this guide and can be seen in Appendix E.

4.2.3 Curriculum Requirements

It is important for the teacher to know which requirements of the U.K. curriculum are satisfied so that their complete lesson goals can be accomplished. Each requirement from the curriculum that is satisfied is bolded and a description of which parts of the interactive learning module satisfy that certain requirement is added so that the teacher will have a firm grasp of how each requirement is fulfilled. A section of the KS3 guide is as follows:

Classifying materials

1. Pupils should be taught:
   - **a. How materials can be characterised by melting point, boiling point, and density.**
   - **b. How the particle theory of matter can be used to explain the properties of solids, liquids, and gases, including changes of state, gas pressure, and diffusion.**

As presented in Section 4.2.3, Figure 4.10 is part of the curriculum-module grid. The KS3 grid displays information regarding which items and questions satisfy which requirements from the U.K. National Curriculum. This is shown in Figure 4.10 below. Refer to Appendix E for the complete list of KS3 curriculum requirements.

Shelld Q1	Kite Sheild Q2	Broadsword	Broadsword Q1	Broadsword Q2	Bow and Arrow	Bow and Arrow Q1	Bow and Arrow Q2	Vambrace	Vambrace Q1	Vamrace Q2	
											Classifying Materials
							◆	◆	◆		1a. Melting pt. Boinling pt. Density
◆	◆	◆	◆	◆			◆	◆	◆		1.b Particle theory of matter
											Elements, Compoinds, and Mixtures
											1c. Periodic table
◆	◆	◆		◆		◆					1d. Physical properties
											1e. Elemental combination through chemical reactions
				◆		◆					1f. Compund formulae and word equations
											1g. Mixture constituens may not be combined
											1h. How to separate mixtures
											Changing Materials
				◆		◆					2a. Through Physical change mass is conserved
											2b. Variation of solubility
				◆	◆						2c. Change of state and energy transfers

Figure 4.10 Screen shot of KS3 curriculum matrix

4.2.4 KS3 Official Detective's Notebook

The front page of *The Official Detective's Notebook* for KS3 students is shown in Figure 4.11.

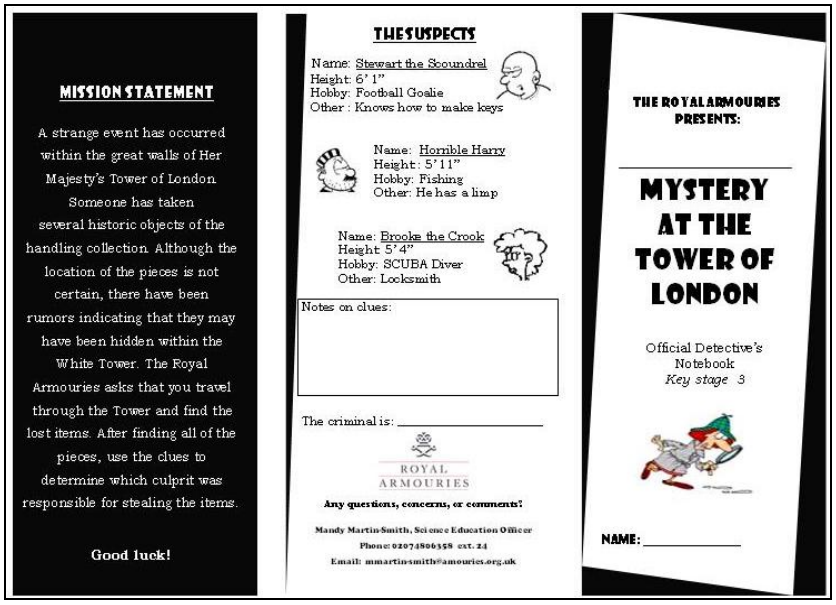

Figure 4.11 Front page of the KS3 *Official Detective's Notebook*.

The content for the KS3 students is tailored more to their needs and abilities. For the KS3 students a "Mission Statement" is used to present the problem and the tasks required of the students. The suspects are provided on the back of the pamphlet (middle third of Figure 4.16). The suspects have a description attached to their mug shot and will be essential for the students to use to determine who the culprit was. Figure 4.12 depicts the inside page of the *Notebook*.

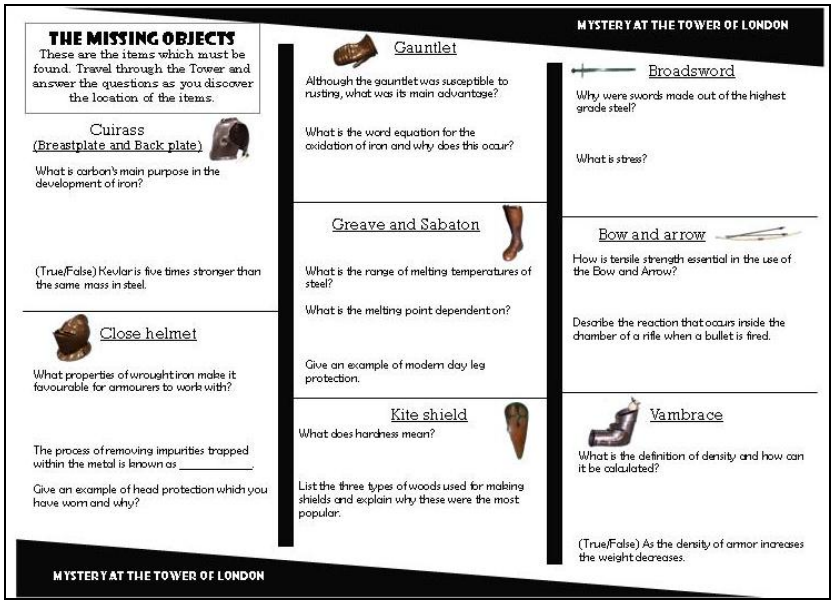

Figure 4.12 Inside page of the KS3 *Official Detective's Notebook.*

This section of the *Detective's Notebook* varies significantly in the content of the material presented to the students. The succession of items remains the same but the questions are much more involved and require the students to look deeper for answers in the material that is provided as suggested by the U.K. National Curriculum. The level of difficulty of the material science questions in conjunction with the clues to be discovered makes this module very exciting, interactive, and educational.

4.3 KS1 Learning Module

The KS1 learning module design follows the KS3 module very closely. The framework that was developed for the KS3 students is still used for the KS1 students. The major difference in the KS1 is the difficulty and decreased range of knowledge that is covered. The information that is provided for KS1 students is curved towards general material science requirements. There are fewer questions that a student needs to answer in this module too.

4.3.1 KS1 Mystery at the Tower of London

The Mystery at the Tower of London for KS1 students does not vary significantly from that of the KS3 mystery. The items, the visualization, and the set-up have all remained the same. In order to solve this mystery, students will have to answer less difficult material science questions correctly in order to obtain clues that will lead to the criminal. Each question will test the student's knowledge of material science concepts and each clue will test the students' detective skills. The storyboard for the KS1 learning module is displayed in the following figures.

Figure 4.13 is the introductory frame of the KS1 learning module and is different than that of the KS3 module because in this case there is a cartoon frog as the narrator of the story. Fredrick has had his items taken from him and he is requesting the students' help.

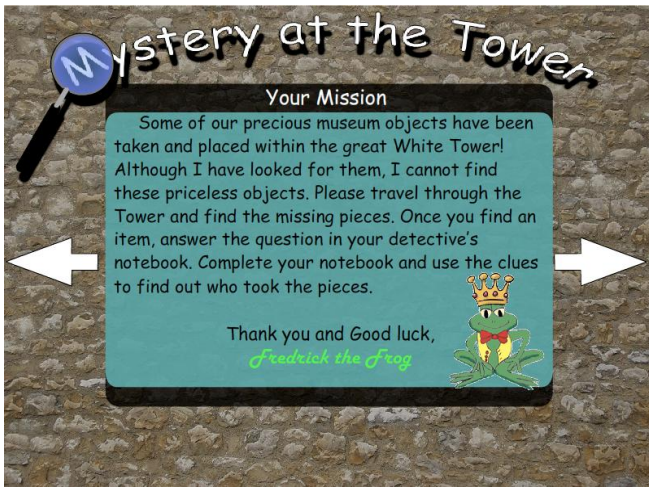

Figure 4.13 KS1 mission frame and interface.

The rooms where the students find the missing objects are the same as the KS3 learning module. Refer to Section 4.2.1 to see an example of a missing object.

Once the student has found a missing item and clicked on it they will see an information screen as shown in Figure 4.14. The informational frame provides the student with material science information related to the object that they have just found. This information is at a much lower difficulty level for the younger students.

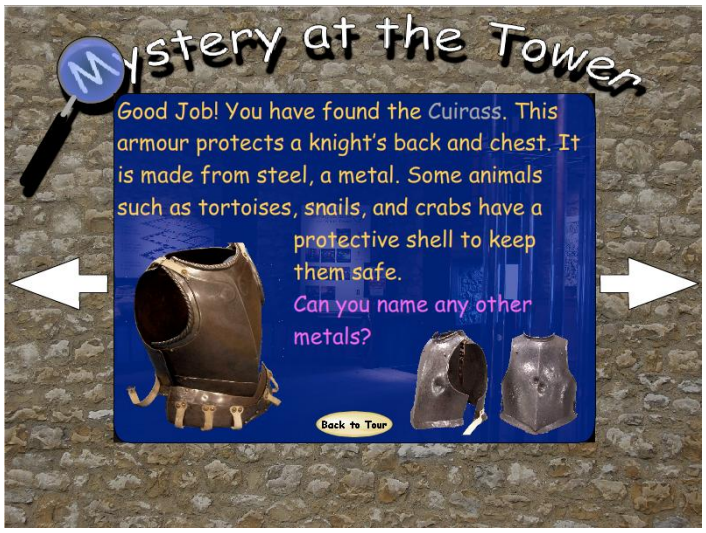

Figure 4.14 KS1 item information frame.

The other aspect of the *Mystery at the Tower* is the clue symbol that the students will encounter. The clue symbols that KS1 students will find are the same as that of the KS3 learning module. Refer to Section 4.2.1 for an example of the clue symbol. The questions found on the clue slides are better tailored to KS1 students. An example clue question can be found in Figure 4.15.

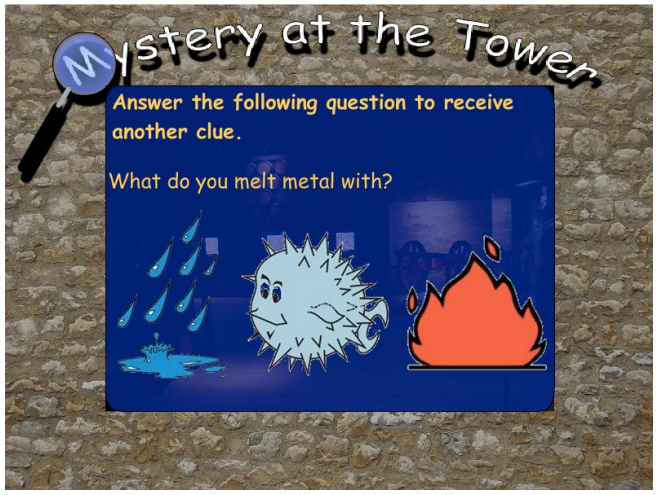

Figure 4.15 Sample clue question.

Figure 4.16 is a sample clue that the student will receive upon selecting the correct answer to the question. There is room for the student to take notes on the clues on the back of their *Official Detective's Notebook*.

Figure 4.16 Sample clue.

Figure 4.17 is the final frame that the students will encounter in the module much like in the KS3 module. The process for selecting wrong or right answers is the same as in the KS3 learning module.

Figure 4.17 KS1 accusing the suspect frame.

4.3.2 Teacher Materials

Refer to Section 4.2.2 for a description of the KS3 *Teacher's Guide* and Appendix D for the complete KS1 guide.

4.3.3 Curriculum Requirements

In order to demonstrate how each curriculum requirement is satisfied for KS1 requirements a curriculum-module grid has been developed that shows which parts of the module satisfy each targeted curriculum requirement and which curriculum requirements are satisfied throughout the tour. This grid is shown in Figure 4.18. Refer to Chapter Four Section 4.2.3 for more information on curriculum requirements.

usword	Broadsword Q1	Bow and Arrow	Bow and Arrow Q1	Bow and Arrow Q2	Vambrace	Vambrace Q1	
							Grouping Materials
◆							1a. Using senses to explore differences between materials
◆	◆		◆	◆	◆		1b. Sorting objects based on simple material propertes
◆		◆	◆				1c. Recognize common types of materials and that some are natural
◆			◆				1d. Find out about material uses based on their simple properties
							Changing Materials
	◆			◆	◆		2a. Shapes of objects can be changes through various processes

Figure 4.18 Screen shot of the Curriculum matrix

This tool allows teachers to identify specific parts of the module that they may want to emphasize as well. For the complete list of KS1 curriculum requirements refer to Appendix D.

4.3.4 KS1 Official Detective's Notebook

The Official Detective's Notebook is as much a way for students to feel that they are a part of a real mystery, as it is a way to provide them with a guided learning experience. The notebook is a tool for students to use to help guide them throughout the mystery as well as provide them with questions to find answers for while searching for the missing items. Figure 4.19 depicts the front-page layout of the pamphlet-style notebook that includes Frederick the Frog's request to help him solve the mystery. Teachers are suggested to print the KS1 notebook in A3, a larger page size, so that there will be more space for the students to use and the images will be larger for easier recognition.

The front cover of the *Detective's Notebook* (right third of Figure 4.19) allows the student to write their name in so that each student can personalise their experience. The inside page of the notebook (left third of Figure 4.19) has Fredrick the Frog and his explanation of what has happened at the Tower. The team also hopes to create a more enjoyable experience for the students, thus the team has used cartoon characters that the team has created. The enjoyment level of the tour is measured and presented in Section 4.5.

Figure 4.19 Front cover of the KS1 *Official Detective's Notebook*.

The back page of the notebook (middle third of Figure 4.19) depicts the three suspects that may have been responsible for the lost items. Based upon the students' successful gathering of the clues, each student can apprehend the culprit at the end of the mystery. The inside pages of the notebook are shown in Figure 4.20.

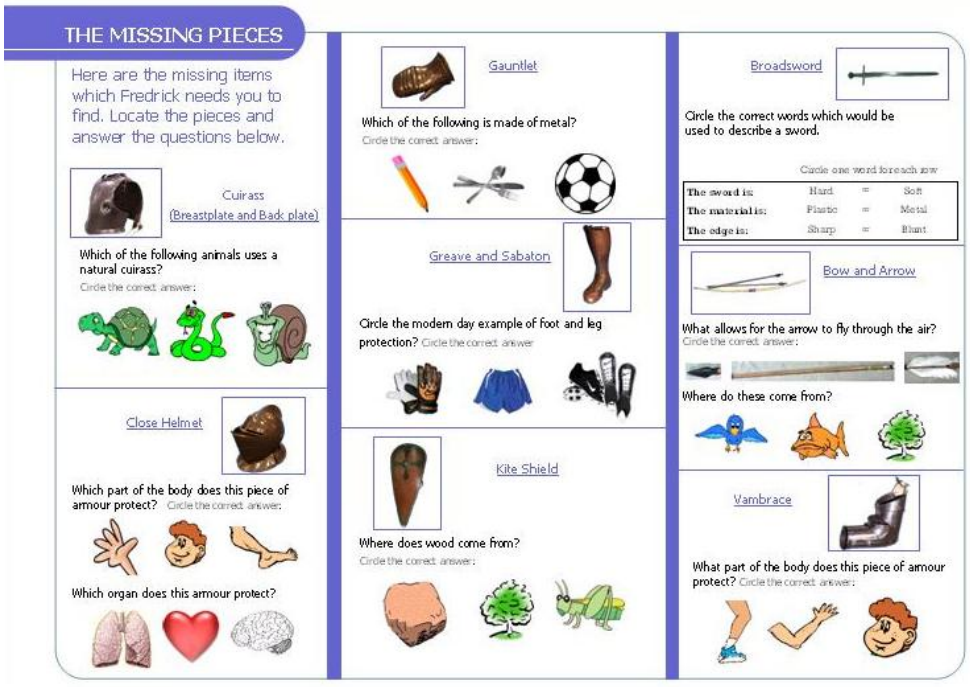

Figure 4.20 Back cover of the KS1 *Official Detective's Notebook*.

The inside pages are where the student will have questions that he or she will need to answer. The items follow the same progression as they are found in the tour. After learning about one of the items they will be able to answer the question that follows. The clue questions are very similar and each one tests the students' recently acquired knowledge.

4.2.5 Build a Heraldic Shield

The next deliverable is a programme that the students can use to build their own Heraldic shield. This will allow students to create their own personalized shield. Different Heraldic symbols are provided for each student to mix match and arrange however they choose. The student will be able to add their name to the shield and print it out to keep. An example of a Heraldic Shield is shown in Figure 4.21.

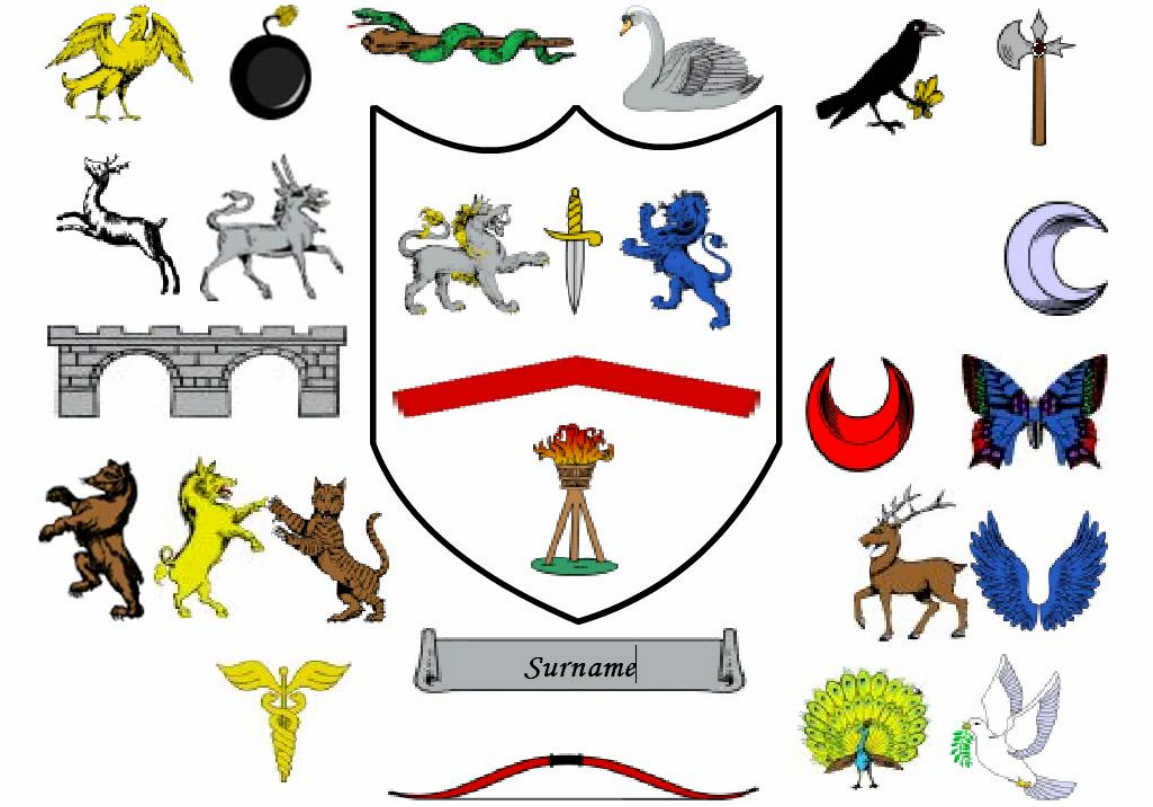

Figure 4.21 Heraldic shield example.

The students will benefit from being able to create a shield and learn some basic information about shields and the symbols that they have selected. The emphasis of this module is to encourage creativity while learning some basic facts about Literacy and Design and Technology during the process.

The figure above is a screen shot of the KS1 version of the *Heraldic Shield Maker*; the KS3 version is slightly more complex with input text fields on either side of the shield that prompt students to explain why they chose each symbol and to explain what materials they would use to make both a modern day and Medieval shield. Accompanying this programme is a table that details the name and meaning of each symbol included in this programme.

4.4 U.K. Teachers' Assessment

As part of the results, the team was able to obtain feedback from several different teachers throughout the U.K. The team had two separate opportunities, as discussed in the subsequent sections, to have teachers evaluate the learning modules and provide feedback that the team utilised before completion of the project.

4.4.1 Teacher's Conference

On Friday April 7, 2006 fifteen U.K. teachers came to the Education Centre for a teacher's conference, which presented the team with its first opportunity to get some feedback on the interactive learning module that was developed. After allowing fifteen KS2-KS5 teachers to interact with the module and ask questions the team was overwhelmed with very positive oral feedback. Each teacher felt that the information that was presented was both intellectually stimulating as well as engaging. One particular aspect of interest was the use of the *Official Detective's Notebook* to test the student's acquired knowledge. Most teachers had not had experience with presenting their students with interactive learning modules as the team had created. This lack of experience encouraged the team to ensure that the *Teacher's Guide* contained very explicit instructions. Many also commented on the dynamics of the module and how they felt that their students would be excited to see a mystery as a part of the classroom experience. The interest from the teachers was encouraging and demonstrated that a significant percentage of the teachers appeared to be interested in using the educational modules in their classrooms.

4.4.2 St. George's Middle School

As another important assessment of the learning modules, the team brought the learning modules to Andy Scott, the head of the science department at St. George's Middle School. Andy was presented with the *Teacher's Guide* and was asked to follow the instructions presented in the guide. The team observed that Andy quickly understood the story that he was to present to his students and he commented later that the instructions were easy to follow. Andy felt that the *Curriculum Matrix* was a very key ingredient to the interactive learning module. He was impressed that the curriculum had been laid out in a comprehensive form with definitive marks where each of the requirements is addressed by certain questions throughout the module. Andy gave the entire learning module the highest rating of six. Andy's only critical comment was that he felt that the information was slightly difficult for his Year 7 (age 11) students. Since Year 7 is the youngest group in Key Stage 3, Andy did feel that the information was likely to be appropriate for all the other age groups

4.5 U.K. Students' Assessment

As per the methods in Section 3.3.3 the team visited St. George's Middle School on the Isle of Sheppey on Friday April 21, 2006. Andy Scott teaches a science class for KS3 students and was kind enough to let us pilot our learning module on his students. The team provided Andy with the necessary *Teacher's Guide* and observed how the class quickly became involved in the mystery. It was evident that the students were very excited to become part of this mystery and solve the crime. The learning module

provided a different method of teaching than the students were normally accustomed to. The team observed the students while they were completing the module and found that the students were quickly absorbed by the information provided.

4.5.1 Self-Assessment Survey

Upon completion of the mystery, each student was asked to fill out a self-assessment survey as shown in Appendix C. The feedback from the survey was overwhelmingly positive. The students' average overall rating of the module was a 5.2 with 6 being the highest score. From the surveys, the team was also able to conclude that the students also found the module easy to use and very informative. The ease of use of the module was rated, on average, a 4.62 out of 6. The students also rated the amount that they learned at 4.62 out of 6 as well. Refer to Appendix F to see all of the data collected from the surveys as well as all of the graphs for all of the data. Figure 4.22 is a graph that shows the distribution of the overall rating of the module from both male and female students.

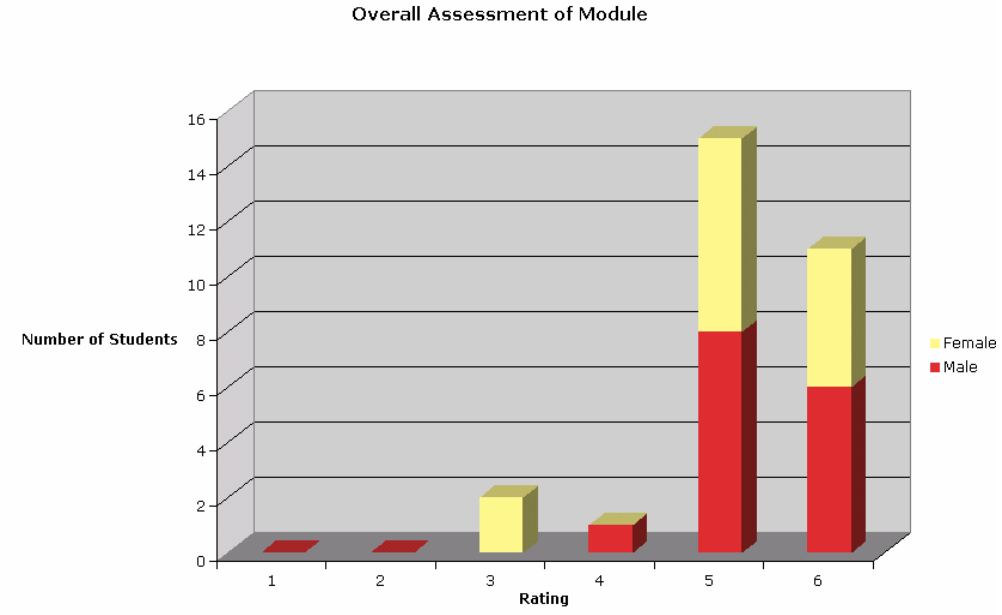

Figure 4.22 Overall rating of learning module.

Through observation the team found that the module piqued the interest of several students to explore some of the open-ended questions presented throughout the learning module.

4.5.2 Evaluation of Detective's Notebooks

The last part of the assessment was taking all of the completed *Official Detective's Notebooks* and recording the responses given for each of the questions. It was obvious that most of the students were gathering the correct information and providing thoughtful answers to the questions. Figure 4.23 shows the breakdown of each of the answers that the students gave for each of the questions. Each answer was divided into four categories as follows:

CS - Denotes a student's response that was correct and displayed some substantial effort and subject knowledge.
C – Denotes a student's response that was correct.
I – Denotes a student's response that was incorrect.
B – Denotes a student's response that was left blank.

	CS	C	I	B	Total
Cuirass Q1	7	13	6	2	28
Cuirass Q2*	1	16	8	3	28
Close Helmet Q1	6	17	3	2	28
Close Helmet Q2*	1	24	2	1	28
Close Helmet Q3	2	21	1	4	28
Greave and Sabaton Q1*	0	25	2	1	28
Greave ad Sabaton Q2	3	22	2	1	28
Greave and Sabaton Q3	0	26	1	1	28
Gauntlet Q1	3	22	2	1	28
Gauntlet Q2	5	7	10	6	28
Kite Sheild Q1	6	18	2	2	28
Kite Sheild Q2	5	18	3	2	28
Broadsword Q1	7	17	1	3	28
Broadsword Q2	4	21	0	3	28
Bow and Arrow Q1	8	6	6	8	28
Bow and Arrow Q2	7	5	5	11	28
Vambrace Q1	6	8	3	11	28
Vamrace Q2*	0	11	7	10	28

Figure 4.23 Distribution of answered questions.

It was also noted that 73% of the students provided correct answers to the questions. It was noted that 29% of answers considered wrong answers were a result of the time constraints upon the students. It was found that students were answering all of the questions correctly but then left the last few blank. In this case several students were asked to stop working before finishing all of the questions. This assessment proved to be very valuable as it was evident that the students enjoyed the experience and more importantly learned the material science concepts as well.

4.6 Summary

Overall, the development of both learning modules successfully completes the goal of presenting KS1 and KS3 students with material science education using the handling collection at the Royal Armouries. More importantly though, these modules are the first resources for the Royal Armouries that provide a means of presenting educational material to students without requiring the students to visit the Education Centre at the Tower of London. This project is the first step in a direction that the Royal Armouries may wish to pursue in other aspects of education. This project addressed material science concepts, but future modules may address other science or history concepts.

Though there are similarities in each of the modules, they are separated so that the needs of each age group are met. The U.K. National Curriculum is very different for each key stage so the team ensured that each set of requirements would be fulfilled with the learning modules developed. *These modules successfully bridged the gap between HM Tower of London and the classroom.* The students receive a unique experience in being able to search the White Tower for pieces of arms and armour that have gone missing, as well as getting a chance to learn material science properties along the way. Their knowledge is immediately tested throughout the mystery in order to collect the clues to

solve the mystery. The teacher can see very quickly if his or her students are starting to understand the material. The teacher is also provided with materials that prove to be very useful in preparing this learning experience for his or her students. Teachers can plan their lesson plan to incorporate the mystery as a supplement to their own classroom teachings. The positive feedback received from both teachers and students alike show that these modules help link the three domains that the team was looking to bridge: the U.K. classroom and HM Tower of London, using the World Wide Web.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

The Royal Armouries is devoted to combining education with the resources that are offered at their different locations. The team witnessed this first hand in the education department within the Tower of London. The Tower constantly supplements the traditional education which U.K. students experience within the classroom. However, almost all of the learning and instruction is completed within the walls of the Tower. While the Royal Armouries Education Department at the Tower is a very effective supplement to classroom learning, no educational resources had been offered outside the Tower. Although parts of the Royal Armouries website aimed at education, it was designed to present the programmes that are offered at the Tower. With the interactive learning modules available for children and school systems, a new dimension appeared within the Royal Armouries website. The modules stood as the first learning resource that a student could complete away from the Tower. Although visiting the Tower would still prove to be very beneficial for children, the web-based programme added another angle towards education which was not previously featured on the Royal Armouries website.

5.1 Conclusions from KS3 Teachers Feedback

On Friday, the 7th of April, the team met with several teachers, many of whom taught Key Stage 3 students. Although brief and very casual, the time spent was quite encouraging. While going through the module, all of the teachers seemed very engaged. Although these teachers seemed to enjoy the programme, their major concern revolved around the educational elements within the module. Overall, they were somewhat unfamiliar with this approach to teaching. To eliminate this concern, the team developed the *Teacher's Guides* to assist educators when utilising the modules which can be seen in Appendix D and E.

5.2 Conclusions from Test Pilot

The ability to observe students completing the module on the final Friday of the team's time on-site experience provided a great deal of insight as to the effectiveness of the module. The team travelled to the Isle of Sheppey and tested the interactive game on Key Stage 3 students.

The students that took part in test pilot were of the youngest age within the KS3 range; all but a few students were 11 years old. While running the programme, the team encouraged the students to ask questions and provide feedback. Most students were able to independently use the module. These students followed the instructions and as a majority were able to successfully complete their *Detective's Notebook* and the mission within the hour time limit. Most of the questions which the students asked revolved around some of the vocabulary. Some children felt that the wording within the module was too difficult. The team took these questions into considerations when analyzing the effectiveness of the module.

5.2.1 Student Assessment Conclusions[3]

The educational aspect of the module, including the strict utilisation the U.K. curriculum, has been the major concern for the team throughout the design. Therefore, the educational response from the students was extremely important in assessing the effectiveness of the programme. This response as well as the results gathered from the assessment led to a number of changes and conclusions to improve the effectiveness of the modules.

Overall, the students found that the module was helpful in learning material science. Students were asked to answer, "How helpful was the Mystery for Learning?" and 86% of the students answered that the programme was more helpful than not[4]. With education being the major concern of the team and the liaison, such a positive response proved that the programme was an effective technique as an alternative approach to teaching. The team did discover, however, that the students were challenged. Drawn from the results, 93% found the notebook more challenging than not and 79% of the students found the clue questions to be more challenging than not. Although this may appear to pose a problem, the other ratings gathered through the student assessments proved otherwise. The students may have found the material to be difficult but the assessment and analysis of the notebooks proved that the module was an appropriate tool towards education.

While the educational piece is vital to the success of the module, the team also had other considerations in assessing the effectiveness. When asked if the module was engaging, 96.5% of the students felt that the module was more engaging than not. Though not as important as is the educational elements, the team needed to ensure that the module would keep the attention of the children. This is where the interactivity of Flash appeared to be vital to the success of the project. The students enjoyed the multiple actions, which the team was able to provide through Flash. Also, because these students found the module to be challenging, the team needed to ensure that the students enjoyed the programme and would not get discouraged.

A key statistic which the team calculated following the test pilot was the rating differences between male and female students. The data gathered showed that the female students found the module to be more difficult to use and also expressed that the information within the module was harder. However, when analyzing the *Detective's Notebooks*, both the males and the females scored equally well. Also, although challenged, the females provided a strong overall rating for the module with an average of 5.1 (with 6 being the best rating). Therefore, the module proved to be an appropriate learning tool and did not strongly favour either sex. Although females expressed a level of difficulty within the programme, they succeeded in answering well and enjoyed using the module as a supplement to classroom teaching.

[3] Based on the results in Chapter 4.

[4] "more helpful than not" indicates that students provided a 4, 5, or 6 on the 1-6 scale (with 6 being the best).

5.2.2. *Detective's Notebook* Conclusions

Another assessment tool, which provided positive results towards the effectiveness of the module, was the team's analysis of the childrens' *Detective's Notebook*. As mentioned above, the students indicated that they felt quite challenged when using the module. However, when analyzing the notebooks, the team concluded that 73% of the answers were actually correct. These results can be seen in Chapter 4. Even more encouraging is that if given more time, the students would have been able to answer many more of the question correctly. When studying the results in Chapter 4, it was very apparent that a much greater percentage of correct answers were those found in the earlier questions within the *Detective's Notebook*. Even more so, out of the total amount of incorrect answers about 29% were the result of a lack of time. Therefore, if given more time, the percent of correct answers would have been much greater.

An essential consideration for the team during the design of the module was ensuring that it would be appropriate for the entire Key Stage in each version of the module. After the results of the pilot test with the KS3 children, the team and the liaison believe that the programme will prove to be suitable for the entire Key Stage. The younger age children who took part in the pilot test found the module quite challenging. Although these children may require more time to successfully complete the module, the results proved they enjoyed the programme and answered most of the questions correctly. Therefore, older children should be able to use the programme with ease and because the module strictly follows the U.K. curriculum, all children within the Key Stage should learn from the material science information within the module.

5.2.3 Module Modifications following Test Pilot

Once the test pilot results had been analyzed, the team was able to make adjustments to both modules to improve future effectiveness. A major modification to the clue questions was put into effect to further emphasize the material science which KS3 students will encounter. The format still remained the same: there are four choices, only one of which is the correct answer. However, after adjusting the programme students who incorrectly answer a question were not longer able to continue selecting the possible answers until finally selecting the correct one. Rather, if a student does not answer correctly, he/she is sent back to an earlier instance in the module which presents the correct answer. In doing so, the student will be forced to take closer notice of material science in order to solve the mystery.

Further alterations were made to stress the importance of completing the *Detective's Notebook*. During the test pilot, the team noticed that some children were simply concentrating on solving the case rather than filling out their notebooks. As a result, the team altered the introductory and closing frames to solve this problem. The introductory frames were changed to present the game in a much more linear fashion, instructing the students that the map should only be utilised after progressing through the module using the navigation arrows. Changes were also made to those frames which students encounter directly before selecting which culprit stole the pieces. Additional frames were inserted at this point stressing that if a student's notebook is not complete, then he/she must use the map and answer all of the questions before solving the case.

As mentioned before, the map led to some problems during the test pilot run with the KS3 students. The students focused on the map and did not use the game in the linear fashion as was designed. From this experience, the team determined to remove the map from the KS1 module. Ranging from five to seven years of age, these children probably would not have been able to comprehend the intention of the map. The students will now be able to concentrate exclusively on the material within the module and the solving of *The Mystery at the Tower.*

5.3 Recommendations

Based on the team's experience while on-site at the Tower of London, the team can provide several recommendations to further expand on the work completed by the team. These recommendations will stand as a continuation of the on-site accomplishments and will only strengthen the impact of the learning module on the visiting students in the future.

5.3.1 Technical Recommendations

One potential difficulty revolving around the implementation of the module upon the Royal Armouries web site is the difficulty with loading time. The interactive modules, designed in Flash, are relatively large files due to the many images and videos. These were designed to make the virtual tour experience as realistic as possible. However, due to the many features of the tour, the size grew rather large. Therefore, school systems many run into difficulties when attempting to download the programme. There are two possibilities which schools could consider when seeking to use the module. The schools could simply allow for the programme to download. With a good Internet connection, the download process should take no more than 10 minutes from the Royal Armouries web-site. Teacher's could download the programme onto their computer and then place it on the school's network. Once on the network, students will have instant access to the programme. Otherwise, the Royal Armouries would need to provide schools with Compact Discs with all of the necessary materials already burnt onto it. This was the technique used by the team during the test pilot. A CD was given to the school and the Flash programme was placed upon the school's network. All of the downloadable information is included for teachers in the *Teacher's Guides* in Appendices D and E.

5.3.2 *Mystery at the Tower of London* Recommendations

Another issue that should be addressed when considering future expansion of the module developed by the team revolves around the idea of continual updating. Although the team put together an effective programme, the Royal Armouries would benefit by updating the information within the tour. The Royal Armouries could accomplish this in two ways: making multiple versions offering different information or updating the team's module. In both cases, the need for some change is clear because Key Stages do not involve only one age. In other words, children from KS3 range from 11 to 14 years of age. Due to this, students could experience an educational module in more than one

school year. However, if the information were the same, there would be little need to experience the programme more than once. Therefore, updating the module would prove quite beneficial.

Making multiple versions of the modules developed by the team would be one way to ensure the information is always fresh. In making multiple versions, the Royal Armouries would not need to alter the initial programme developed by the team. Rather, the "copies" of the original modules would include changes within the tour to provide new information. These versions would follow the same format but would provide each Key Stage with different options. Teachers could chose from three versions, for example, and therefore students in a certain key stage could experience the learning module more than once and learn new information.

The other option for updating would entail substituting the pieces that the team inserted with other objects. In a similar manner, students in each key stage would have the ability to experience the tour multiple times while learning new information. The format of the actual programme would remain the same, but the information within would have been altered to present a fresh module. Although this is a possibility, it is not the route the team would necessarily like to see the Royal Armouries travel down in that the team's module would not remain as it was designed. However, it is an option to ensure that students can obtain new knowledge while experiencing the programme in successive years.

Other issues come into sight when considering updating the team's interactive learning module. These changes must be taken into effect in the future if the Royal Armouries intends to keep up with the updating world. Just as the Royal Armouries should update their teaching lessons around the changing U.K. curriculum, they should update the learning module. The team designed their programme around the current curriculum. Therefore in the future, if the curriculum changes, the team's module will not be useable unless it is updated to include the changes to the curriculum. Another recommendation in the future which must be considered revolves around changes in technology. As of now, the team's modules are strictly to be used within the classroom through web-based learning. However, in the future if the Royal Armouries could incorporate changes in technology to advance the module, then the effectiveness of the programme would grow as technology does.

5.3.3 Reaching out: Future Recommendations

A primary recommendation includes developing tours for the other Key Stages that the team did not focus on. The interactive modules developed by the team proved to be very effective as a result of the data, which was collected on-site. As a result of this success, the Educational Centre could further expand its online learning systems by developing similar programmes for Key Stages 2, 4, and 5. The team's programme revolved around the idea of a virtual tour which brought together web-based learning with the traditional, classroom scenario. Although the team's module required the use of Flash, other simpler programme could be developed in the future and could prove to be just as successful. From the results the team gathered during the test pilot, such a method is effective when conveying educational material in a manner which supplements traditional classroom learning. As such, the modules can stand as an example for future

Royal Armouries programmes to continue to educate students away from the Tower. The module provided a new direction towards teaching that the Royal Armouries had not previously utilised. Continual development on the Armouries website will only draw more students and school systems towards interactive web-based learning.

The educational systems within the United Kingdom are continually utilising the Internet as a way to supplement the classroom as a means of learning. As such, the Armouries should push towards providing schools with multiple options on their site. The Royal Armouries is very effective in bringing school students to the Tower and providing them with a very memorable and educational experience. Such resources on the Internet, similar to the team's modules, would only strengthen the Royal Armouries popularity as a means of teaching science and history to children.

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APPENDIX A: The UK National Curriculum for Material Science

Key Stage 1 (5-7)

Grouping materials

1) Pupils should be taught to:
   a. Use their senses to explore and recognize the similarities and differences between materials
   b. Sort objects into groups on the basis of simple material properties (e.g. roughness, hardness, shininess, ability to float, transparency and whether they are magnetic or nonmagnetic)
   c. Recognize and name common types of material (e.g. metal, plastic, wood, paper, rock) and recognize that some of them are found naturally
   d. Find out about the uses of a variety of materials (e.g. glass, wood, wool) and how these are chosen for specific uses on the basis of their simple properties.

Changing materials

2) Pupils should be taught to:
   a. Find out how the shapes of objects made from some materials can be changed by some processes, including squashing, bending, twisting and stretching
   b. Explore and describe the way some everyday materials (e.g. water, chocolate, bread, clay) change when they are heated or cooled.

Key Stage 3 (11-14)

Classifying materials

1) Pupils should be taught:
   a. How materials can be characterized by melting point, boiling point and density
   b. How the particle theory of matter can be used to explain the properties of solids, liquids and gases, including changes of state, gas pressure and diffusion.

Elements, compounds and mixtures

   a. That the elements are shown in the periodic table and consist of atoms, which can be represented by symbols
   b. How elements vary widely in their physical properties, including appearance, state at room temperature, magnetic properties and thermal and electrical conductivity, and how these properties can be used to classify elements as metals or non-metals
   c. How elements combine through chemical reactions to form compounds (e.g. water, carbon dioxide, magnesium oxide, sodium chloride, most minerals) with a definite composition
   d. To represent compounds by formulae and to summarize reactions by word equations

e. That mixtures (e.g. air, sea water and most rocks) are composed of constituents that are not combined
f. How to separate mixtures into their constituents using distillation, chromatography and other appropriate methods.

Changing materials

2) Pupils should be taught:

a. That when physical changes (e.g. changes of state, formation of solutions) take place, mass is conserved
b. About the variation of solubility with temperature, the formation of saturated solutions, and the differences in solubility of solutes in different solvents
c. To relate changes of state to energy transfers

Geological changes

a. How forces generated by expansion, contraction and the freezing of water can lead to the physical weathering of rocks
b. About the formation of rocks by processes that take place over different timescales, and that the mode of formation determines their texture and the minerals they contain
c. How igneous rocks are formed by the cooling of magma, sedimentary rocks by processes including the deposition of rock fragments or organic material, or as a result of evaporation, and metamorphic rocks by the action of heat and pressure on existing rocks

Chemical reactions

a. How mass is conserved when chemical reactions take place because the same atoms are present, although combined in different ways
b. That virtually all materials, including those in living systems, are made through chemical reactions, and to recognize the importance of chemical change in everyday situations (e.g. ripening fruit, setting superglue, cooking food)
c. About possible effects of burning fossil fuels on the environment (e.g. production of acid rain, carbon dioxide and solid particles) and how these effects can be minimized.

Patterns of behaviour

3) Pupils should be taught:

a. How metals react with oxygen, water, acids and oxides of other metals, and what the products of these reactions are
b. About the displacement reactions that take place between metals and solutions of salts of other metals
c. How a reactivity series of metals can be determined by considering these reactions, and used to make predictions about other reactions

Acids and bases

a. To use indicators to classify solutions as acidic, neutral or alkaline, and to use the pH scale as a measure of the acidity of a solution
b. How metals and bases, including carbonates, react with acids, and what the products of these reactions are
c. How acids in the environment can lead to corrosion of some metals and chemical weathering of rock [for example, limestone]
d. To identify patterns in chemical reactions.

Source: http://www.nc.uk.net/webdav/servlet

APPENDIX B: Theoretical Education Review

In her review of the problems and issues in education, *The Academic Achievement Challenge*, Chall (2000) explores the two predominant viewpoints being argued. Using a quote from Charles Silberman from *Crisis in the Classroom* in (1970) (page 229), Chall expresses the view that the traditional educational methods expect too much of students, demanding that they sit in their seats for hours at a time and learn and express interest in the subjects being taught, completely disregarding the particular interests or attention span of all each individual student (18). The method which Silberman is attacking is the traditional academic approach to education, which features a curriculum created by the teacher to be taught to all students focusing on the major core academic subjects relevant to the particular course being taught. This method, according to Harold Stevenson and James Stigler from their studies of these two major approaches to teaching is known as the "intellectualist", or traditional, approach and focuses on having the student master core academic subjects. Its rival, the "anti-intellectualist", or progressive, approach is classified by its focus on meeting the needs of individual students by creating an academic curriculum that is tailored to be conducive to their own interests and learning styles (Chall 24).

A recent movement toward the need for a "thinking curriculum" follows the principle that the modern body of scientific knowledge is far too vast to teach all or even most of it to students, and therefore the focus should be shifted towards teaching students how to think and solve problems (i.e. critical thinking) (Chall 24). While the progressive approach has its merits and is currently held in higher popular opinion, it is still not until the latter half of secondary schooling that such skills begin to be heavily stressed (e.g. philosophy, science labs, research papers, etc.), and this is mostly due to the need for students to acquire the basic tools of the various subject areas before being able to apply critical thinking.

Of course, neither methodology is perfect: the traditional approach to education sets up a curriculum indifferent to student interests and cannot possibly maximize each student's potential, as the programmes have to have expectations which all students can meet. Likewise, the progressive approach puts much more stress on the teacher to be innovative, make the material interesting and engaging and appeal to each student's learning preferences and style (Chall 28). Another potential problem with the progressive approach to education could be the gradual decline in the level of "general knowledge" which students would acquire in the traditional curricula. A look into educational methodologies was needed to determine the most effective combination.

To further understand each method, the team analyzed studies that have been conducted on the results of both methods in order to assess the advantages and disadvantages of each.

Stallings and ATB Associates conducted studies on academic achievement in reading, math and language skills in 1975 and 1977, respectively, and found that traditional methods produced more achievement when compared to progressive methods (Chall 80). A similar series of studies done by Adams and Engleman in 1996 produced basically the same conclusion (Chall 80). In 1987, Good and Brophy's synthesis of qualitative studies found that evidence indicated overall that traditional methods were

superior to progressive methods; however, they also concluded that progressive educational methods could be more effective for students who have the motivation and ability to work independent of constant teacher supervision (Chall 83).

According to a meta-analysis conducted by Herbert Walberg in 1990 on elementary and secondary school teaching methods, some positive results of the traditional method when compared to the progressive method were more disciplined behaviour, connections with previous knowledge and material, regular testing, homework assignments with feedback and grades, and more direct teaching (Chall 92). Meanwhile, the progressive approach showed positive results in the areas of problem solving skills, scientific knowledge and attitudes towards science in general. His overall results supported the interpretation that traditional teaching methods bore higher academic achievement when compared to the progressive approach (Chall 92). Thus, based upon Walberg's findings, it would seem that more of a progressive approach to science education would be favourable to stimulate interest and improve attitudes towards science among students in a museum atmosphere, because of the availability of interesting objects the museum has available on display.

APPENDIX C: KS3 Assessment Survey

Please take a few minutes to answer these questions about the learning module.

1. How old are you?

   11 12 13 14 Other (specify):_____

2. Male or Female?

   M F

3. Which section of the science curriculum do you prefer?

   Sc2 – Life processes and living things

   Sc3 – Materials and properties

   Sc4 – Physical processes

4. What is your favourite subject in school?

5. Do you play computer games regularly?

   Yes No

For the following questions please indicate your response by circling one rating between 1 and 6, with 6 being the best.

1. How fun was the *Mystery at the Tower*?

   1 2 3 4 5 6

2. How helpful was the *Mystery* in learning material science?

   1 2 3 4 5 6

3. How easy was the *Mystery* interface to use?

   1 2 3 4 5 6

4. How challenging were the clue questions in the *Mystery*?

   1 2 3 4 5 6

5. How challenging were the questions in the *Detective's Notebook*?

   1 2 3 4 5 6

6. Have you ever learned using a module like this before?

   Yes No

7. Which section of the curriculum did you feel this module addressed?

   Sc2 Sc3 Sc4

8. Have you ever been to the Tower of London before?

   Yes No

9. What was your favourite part of the *Mystery at the Tower*?

10. What is your overall rating of the *Mystery at the Tower*?

    1 2 3 4 5 6

APPENDIX D: Teacher's Guide KS1

Teacher's Guide

Key Stage 1

The following is an instructional guide for the interactive web-based learning module.

Questions, concerns, or comments?
Mandy Martin-Smith
Royal Armouries
Telephone: 020 7488 5658
Email: mmartin-smith@armouries.org.uk

Table of contents

Letter to Teachers:

The following web-based learning module has been developed in order to enhance students' knowledge and understanding of material science and at the same time expose the students to the White Tower at HM Tower of London. The Royal Armouries in cooperation with Worcester Polytechnic Institute have ensured that this learning module addresses several of requirements of the U.K. National Curriculum. The parts of the U.K. curriculum which the module targets are highlighted in later sections. This guide also contains all of the material science information which students will encounter when using the module.

Aside from the virtual tour learning module, another educational programme for students is to *Design your own Heraldic Shield*. The instructions for this programme can be found in a later section.

Note: Both the *Mystery at the Tower of London* as well as the *Design your own Heraldic Shield* programmes were designed using Macromedia Flash 8.

Please continue and read the instructions below.

Thank you.

Mystery at the Tower Instructions:

2. Print *Letter from Fredrick the Frog*.
3. Print KS1 *Official Detective's Notebook* for each student.
    a. Please note: There are both A3 and A4 versions for you to choose depending on your school's printing capabilities.
4. Use the *Letter from Fredrick the Frog* to introduce *The Mystery at the Tower of London* for students.
5. Instructions for running module from the internet:
    a. Navigate to the module via the Royal Armouries website at http://www.royalarmouries.org/ (educational link).
    b. After opening the link and select the module, you will be prompted with a window to "open" or "save". If your school system has a local network, place the module on the network for the quickest and easiest download (choose the "save" option in this case). Otherwise you can open from the internet.
        i. If you do not have Macromedia Flash Player 8, there will be a "plug-in" at the bottom of the web-page to install this programme. After this, the module will be accessible. The module can also be run using Internet Explorer (explained below).
6. Instructions for running the module from Compact Discs:
    a. The CDs will contain all necessary information.
        i. If using the CD to place the programme onto the network, make sure to copy all of the content within the folder that is on the CD, not merely the Flash programme.
        ii. In order to run the *.swf file (the Flash file), you need Macromedia Flash Player. If you do not already have this Flash Player on your network, find and install from: http://wwwmacromedia.com/shockwave/download/download.cgi?P1_Prod_Version=ShockwaveFlash
        iii. If you cannot install Flash Player, the module can be run using Internet Explorer. Simply right click on the *.swf file and select "open with." Then select Internet Explorer and the programme will open.
    b. We strongly recommend that teachers complete the programme prior to introducing it to the students.
7. Please inform your students of the following:
    a. As a way to provide students with the opportunity for further learning, open ended questions are located within the programme. These are not to be answered in the Notebook and were designed to challenge those students who seek more information. As the teacher, it is your decision as to whether or not you would like your students to answer these questions. However, there is not space in the *Detective's Notebook* for such answers. Whatever the case, please inform your students that they will come across such questions.
        i. The text for the open ended questions is **lavender** in colour.
8. Upon completion have each student hand in his or her *Official Detective's Notebook* for assessment.
9. Print the *Royal Armouries Certificate*, sign, and present to each student.

* If attending HM Tower of London, have each student bring his or her *Official Detective's Notebook* for further use.

Instructions for Heraldic Shield:

The following is the instructional page which your students will encounter upon opening the heraldic shield programme:

Welcome to the Royal Armouries Heraldic shield maker. To begin, click the continue button on the bottom of the page.

On this page you can see all the symbols you may choose from to make your own heraldic shield. Only five symbols at most can fit in the shield. Once you have decided which symbols you want to use, click on the continue button at the bottom of the page.

Now click on each symbol you want to use and drag it inside the shield. Once you are done, click inside the banner below the shield and enter your surname. Once you have finished, wait for the teacher to print your shield. Once it is printed, cut out your shield and finish it by colouring it in.

*Please note: The children are instructed to ask the teachers for assistance when printing. Once they are ready to print, click on the file menu, and choose the print option. In the print menu, choose a landscape orientation for the paper to make the shield prints correctly. Select "OK" to print each student's shield.

**The Heraldic Shield programme aims to satisfy certain curriculum requirements within the Design and Technology programme of study for Key Stage one. It encourages pupils to "develop their designing and making skills" by offering them a collection of heraldic symbols to choose from. In keeping with the curriculum requirements, pupils could be asked to, "Use 2D and 3D models to try out and develop ideas as they become more reflective about their designs." They can create a 2D paper version or using this as a design carry out a further DT activity to produce a 3D version of the shield using a variety of materials.

Letter to Students:

Dear _____ class,

Hello students, my name is Fredrick the Frog and I need your help. At HM Tower of London the Royal Armories Education Department has many unique handling objects that visitors are allowed to hold and touch. Many of the objects are real pieces of arms and armour. The Royal Armouries is often very busy because so many students visit everyday and mysteriously some of the handling objects have been taken. Please help me by solving *The Mystery at the Tower of London*.

I recently heard that the pieces have been misplaced in the White Tower. Although I have looked for them, I was unsuccessful in finding them. You have been given an *Official Detective's Notebook* that has a picture of each of the missing items. Your job as the *Detective* is to go through the White Tower and find them. Along the way you will need to gather information about the science within the items in order to make sure they are the correct objects. You will also encounter clues throughout your travels. These clues will provide you with information to determine which of the three suspects on the back of your notebook was actually responsible for stealing the items. However, in order to receive the clue, you must correctly answer a question. Answer all of the questions, receive all of the clues, and catch the culprit. Good luck *Detectives*!

Sincerely Yours,

Fredrick the Frog

Satisfied Curriculum Requirements for Material Science

Key Stage 1 (i.e. ages 5-7, all areas covered in the module)

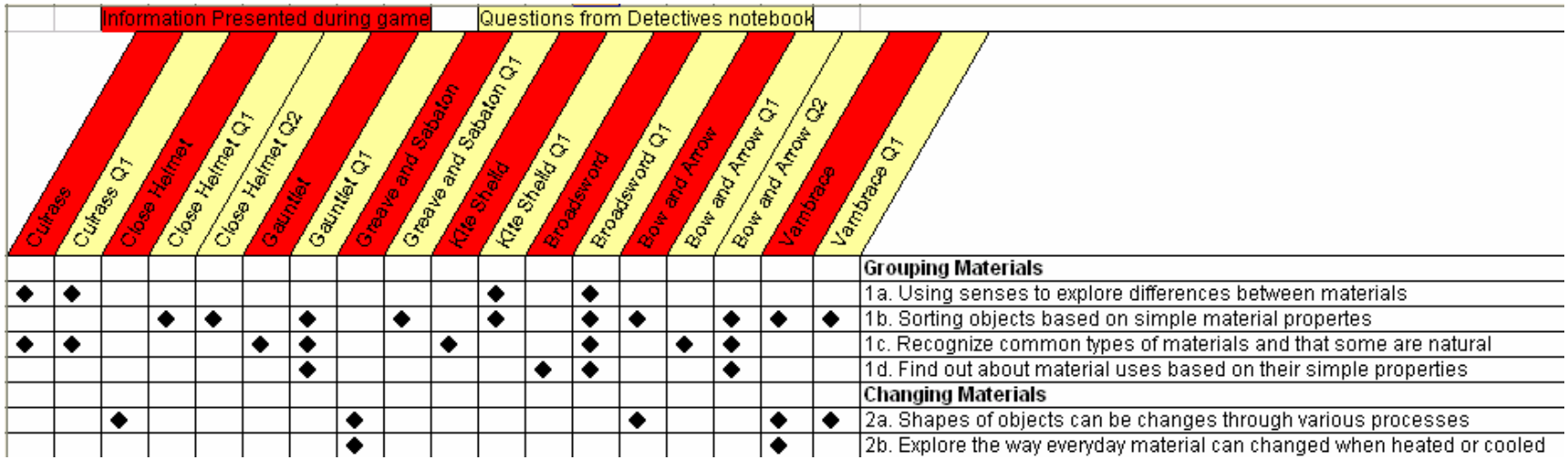
Grouping materials

1. Pupils should be taught to:
    a. **Use their senses to explore and recognize the similarities and differences between materials.**
    b. **Sort objects into groups on the basis of simple material properties (e.g. roughness, hardness, shininess, ability to float, transparency, and whether they are magnetic or nonmagnetic).**
    c. **Recognize and name common types of materials (e.g. metal, plastic, wood, paper, rock) and recognize that some of them are found naturally.**
    d. **Find out about the uses of a variety of materials (e.g. glass, wood, wool) and how these are chosen for specific uses on the basis of their simple properties.**

Changing materials

2. Pupils should be taught to:
    a. **Find out how the shapes of objects made from some materials can be changed be some processes, including squashing, bending, twisting, and stretching.**
    b. **Explore and describe the way some everyday materials (e.g. water, chocolate, bread, clay) change when they are heated or cooled.**

U.K. Curriculum Matrix



	Information Presented during game										Questions from Detectives notebook								
	Cuirass	Cuirass Q1	Close Helmet	Close Helmet Q1	Close Helmet Q2	Gauntlet	Gauntlet Q1	Greave and Sabaton	Greave and Sabaton Q1	Kite Shield	Kite Shield Q1	Broadsword	Broadsword Q1	Bow and Arrow	Bow and Arrow Q1	Bow and Arrow Q2	Vambrace	Vambrace Q1	
																			Grouping Materials
	◆	◆									◆		◆						1a. Using senses to explore differences between materials
				◆	◆		◆		◆		◆		◆	◆		◆	◆	◆	1b. Sorting objects based on simple material propertes
	◆	◆				◆	◆			◆			◆		◆	◆			1c. Recognize common types of materials and that some are natural
							◆					◆	◆			◆			1d. Find out about material uses based on their simple properties
																			Changing Materials
			◆					◆						◆			◆	◆	2a. Shapes of objects can be changes through various processes
								◆									◆		2b. Explore the way everyday material can changed when heated or cooled

Material Science information within the module:

Cuirass (breast and back plate combination):
"Good Job! You have found the Cuirass. This armour protects a knight's back and chest. It is made from steel, a metal. Some animals such as tortoises, snails, and crabs have a protective shell to keep them safe."

Close Helmet:
"Fantastic! You've found the Close Helmet. It's also made of steel. This helmet was made to protect a knight's head. The visor goes up and down so that a knight can see better."

Greave and Sabaton:
"Great! You've found the Greave and Sabaton. This armour protects the leg and foot. It is made from steel, which had to be heated so that the armour makers could bend it into shape."

Gauntlet:
"Excellent! You've found the Gauntlet. This piece of armour was used for hand protection. It is made of many pieces of overlapping metal that allows the knight to move his hand freely. Animals like the armadillo have boney plates that work in the same way."

Kite Shield:
"Splendid! You've found the Kite Shield. It is made from natural materials – wood from trees, iron from rocks, and leather from dead animals."

Broadsword:
"Awesome! You've found the Broadsword. This was a common type of sword hundreds of years ago. The blade is made from the hardest type of steel to stop breaking or bending during use."

Bow and arrow:
"Well done! You've found the Bow and Arrow. The bow was made of wood and could bend to allow an archer to shoot an arrow. To make the arrow go a long way, it needs to be straight, light, and have feathers at the end."

Vambrace:
"Nice Job! You've found the Vambrace. This armour is jointed to protect the elbow and allow arm movement. This piece of armour is very shiny but the metal becomes dull and changes colour over time. This brown colour is called rust. The sweat from our fingers helps this to form, so we have to clean our armour regularly and wear gloves to protect it."

OPEN-ENDED QUESTIONS (found within the programme):

Can you name any other metals?
In what sports do you need to wear helmets?
Where in the world could you find armadillos?
How hot does it need to be to make steel bend easily?
Why don't we make swords out of hard rock?
How could you stop armour from rusting?

APPENDIX E: Teacher's Guide KS3

Teacher's Guide

Key Stage 3

The following is an instructional guide for the interactive web-based learning module.

Questions, concerns, or comments?
Mandy Martin-Smith
Royal Armouries
Telephone: 020 7488 5658
Email: mmartin-smith@armouries.org.uk

TABLE OF CONTENTS:

Letter to Teachers:

The following web-based learning module has been developed in order to enhance students' knowledge and understanding of material science and at the same time expose the students to the White Tower at HM Tower of London. The Royal Armouries in cooperation with the Worcester Polytechnic Institute have ensured that this learning module addresses several of requirements of the U.K. National Curriculum. The parts of the U.K. curriculum which the module targets are highlighted in later sections.

This guide also contains the material science information which your students will encounter within the module. The underlined/asterisked words are those which are active links within the module and provide students with more information. There are also buttons in the programme which are labelled "more" to present additional material. The guide follows a very similar format as is seen within the web-based programme.

Aside from the virtual tour learning module, another educational programme for students is to *Design your own Heraldic Shield*. The instructions for this programme can be found in a later section.

Note: Both the *Mystery at the Tower of London* as well as the *Design your own Heraldic Shield* programmes were designed using Macromedia Flash 8.

Please continue and read the instructions listed below.

Thank you.

Mystery at the Tower Instructions:

10. Print Letter from the Royal Armouries.
11. Print KS3 *Official Detective's Notebook* for each student.
12. Use the Letter from the Royal Armouries to introduce *The Mystery at the Tower of London* for students.
13. Instructions for running module from the internet:
    a. Navigate to the module via the Royal Armouries website at http://www.royalarmouries.org/ (educational link).
    b. Download the supporting files "zip" folder which contains various links which are included within the module. Unzip and the programme will run correctly. Right-click on the zipped folder and choose the unzip option.
    c. After opening the link and select the module, you will be prompted with a window to "open" or "save". If your school system has a local network, place the module on the network (in the same location as the supporting files folder you downloaded in the previous step) for the quickest and easiest download (choose the "save" option in this case). Otherwise you can open from the internet.
        i. If you do not have Macromedia Flash Player 8, there will be a "plug-in" at the bottom of the web-page to install this programme. After this, the module will be accessible. The module can also be run using Internet Explorer (explained below).
14. Instructions for running the module from Compact Discs:
    a. The CDs will contain all necessary information.
        i. If using the CD to place the programme onto the network, make sure to copy all of the content within the folder that is on the CD, not merely the Flash programme.
        ii. In order to run the *.swf file (the Flash file), you need Macromedia Flash Player. If you do not already have this Flash Player on your network, find and install from: http://wwwmacromedia.com/shockwave/download/download.cgi?P1_Prod_Version=ShockwaveFlash
        iii. If you cannot install Flash Player, the module can be run using Internet Explorer. Simply right click on the *.swf file and select "open with." Then select Internet Explorer and the programme will open.
    b. We strongly recommend that teachers complete the programme prior to introducing it to the students.
15. Please inform your students of the following:
    a. As a way to provide students with the opportunity for further learning, open ended questions are located within the programme. These are not to be answered in the Notebook and were designed to challenge those students who seek more information. As the teacher, it is your decision as to whether or not you would like your students to answer these questions. However, there is not space in the *Detective's Notebook* for such answers. Whatever the case, please inform your students that they will come across such questions.
        i. The text for the open ended questions is **lavender** in colour.
16. Upon completion have each student hand in his or her *Official Detective's Notebook* for assessment.
17. Use the attached Material Science information to evaluate each of the student's notebooks.
18. Print *Royal Armouries Certificate*, sign, and present to each student.

* If attending HM Tower of London, have each student bring his or her *Official Detective's Notebook* for further use.

Heraldic Shield Instructions:

The following is the instructional page which your students will encounter upon opening the heraldic shield programme:

Welcome to the Royal Armouries Heraldic shield generator. On the next page you will find the twenty-six symbols available for use to create your own heraldic shield. Each symbol has a meaning associated with it that you may wish to use to better portray the characteristics or values of yourself or your family. You can find a link to this page by simply clicking on one of the symbols in the top row.

When you have viewed all the symbols available to you, click on the continue button in the bottom centre to continue to the next page. Once on the next page, pick which symbols you wish to use and drag them into the shield by clicking on the symbol, dragging it into the blank shield, and releasing the symbol where you wish to place it. Once you have chosen which symbols you wish to use, click and drag each remaining symbol off the page and release the mouse button to make the symbol disappear. Be sure to drag all unwanted symbols off the page, as any left on the page will print. Once you have completed this, click inside the banner located below the shield to enter you surname within the box, then click on the input text boxes found below each question to enter your answer.

When you are satisfied with everything, click on the file menu, and choose the print option to print the page. In the print menu, choose a landscape orientation for the paper to make the shield print to scale correctly. Once the shield has printed, finish it by colouring in the white space within the shield.

*For CD version, there will be a file titled, “Shield instructions.pdf” . Students should be told to open this file to read these instructions. This file also contains all of the information regarding the meanings of all of the symbols. If running from the internet, this file will be found under the same title and an active link can also be found within the shield programme for students to use.

*The Heraldic Shield programme aims to satisfy certain requirements, both within the Design and Technology and the Literacy curricula.

In terms of Design and Technology, the pupils could use the design as a template to produce a 3D version in a variety of materials, such as acrylic.

As part of Literacy, “Schools should use every opportunity to help pupils practice and extend their literacy skills in other areas of the curriculum.” The shield activity will allow pupils to achieve this as it serves not only as a comprehension exercise but also encourages them to express their views by explaining their choice of symbols.

Letter to Students:

Dear _____ class,

At Her Majesty's Tower of London the Royal Armouries Education Department has many unique handling objects that visitors are allowed to hold and touch. Many of the objects are authentic pieces of arms and armour. The Royal Armouries is often very busy because so many students visit everyday and mysteriously some of the handling objects have been taken. By request of the Royal Armouries, each student has been asked to solve *The Mystery at the Tower of London*.

Recently, the Royal Armouries has received word that the pieces may be hidden within the White Tower. You have been given an *Official Detective's Notebook* that has a picture of each of the missing items. Your job as the Detective is to go through the White Tower and find them. Along the way you will need to gather information about material properties of items in order to make sure they are the correct items. You will also encounter clues throughout your travels. However, in order to receive the clue, you must correctly answer a question. Answer all of the questions, receive all of the clues, and catch the culprit. Good luck Detectives!

Sincerely Yours,

The Royal Armouries

Satisfied Curriculum Requirements for Material Science:

Key Stage 3 (i.e. ages 11-14)

Classifying materials

1. Pupils should be taught:
    a. **How materials can be characterized be melting point, boiling point, and density.**
    b. **How the particle theory of matter can be used to explain the properties of solids, liquids, and gases, including changes of state, gas pressure, and diffusion.**

Elements, compounds, and mixtures

c. **That the elements are shown in the periodic table and consist of atoms, which can be represented by symbols.**
d. **How elements vary widely in their physical properties, including appearance, state at room temperature, magnetic properties and thermal and electrical conductivity, and how these properties can be used to classify elements as metals or non-metals.**
e. **How elements combine through chemical reactions to form compounds (e.g. water, carbon dioxide, magnesium oxide, sodium chloride, most minerals) with a definite composition.**
f. **To represent compounds by formulae and to summarize reactions by word equations.**
g. That many mixtures (e.g. air, sea water, and most rocks) are composed of constituents that are not combined.
h. How to separate mixtures into their constituents using distillation, chromatography and other appropriate methods.

Changing materials

2. Pupils should be taught:
    a. **That when physical changes (e.g. changes of state, formation of solutions) take place, mass in conserved.**
    b. **About the variation of solubility with temperature, the formation of saturated solutions, and the difference in solubility of solutes in different solvents.**
    c. **To relate changes of state to energy transfers.**

Geological changes

d. How forces generated by expansion, contraction and the freezing of water can lead to the physical weathering of rocks.
e. About the formation of rocks by processes that take place over different timescales, and that the mode of formation determines their texture and the minerals they contain.

f. How igneous rocks are formed by the cooling of magma, sedimentary rocks by processes including the deposition of rock fragments or organic material, or as a result of evaporation, and metamorphic rocks by the action of heat and pressure on existing rocks.

Chemical reactions

g. How mass is conserved when chemical reactions take place because the same atoms are present, although combined in different ways.

h. That virtually all materials, including those in living systems, are made through chemical reactions, and to recognize the importance of chemical change in everyday situations (e.g. ripening fruit, setting superglue, cooking food).

i. About possible effects of burning fossil fuels on the environment (e.g. production of acid rain, carbon dioxide, and solid particles) and how these effects can be minimized.

Patterns of behavior

3. Pupils should be taught:

a. How metals react with oxygen, water, acids, and oxides of other metals, and what the products of these reactions are.

b. About the displacement reactions that take place between metals and solutions of salts of other metals.

c. How a reactivity series of metals can be determined by considering these reactions, and used to make predictions about other reactions.

Acids and bases

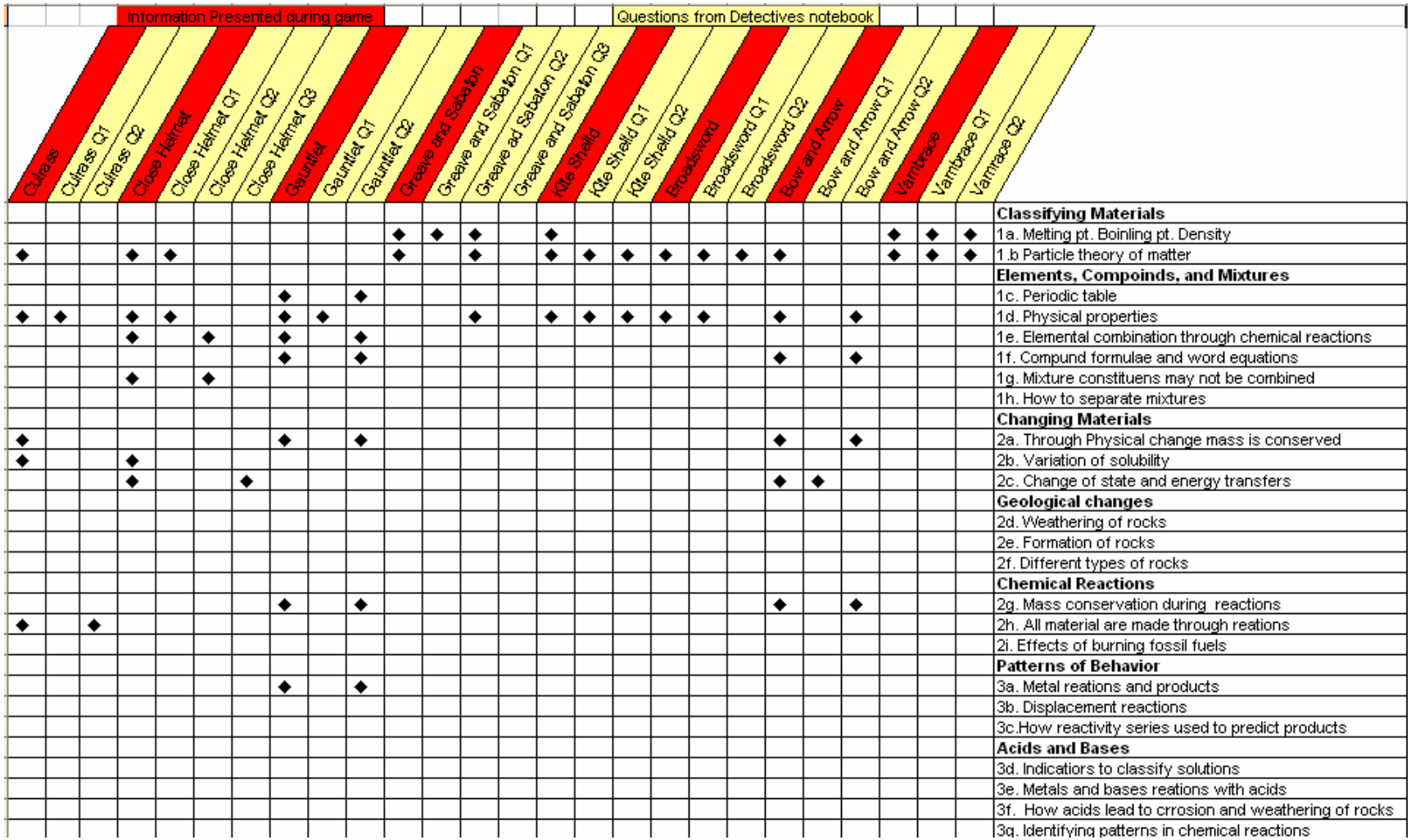
d. To use indicators to classify solutions as acidic, neutral, or alkaline, and to use the pH scale as a measure of the acidity of a solution.

e. How metals and bases, including carbonates, react with acids, and what the products of these reactions are.

f. How acids in the environment can lead to corrosion of some metals and chemical weathering of rock (e.g. limestone).

g. To identify patterns in chemical reactions.

U.K. Curriculum Matrix:



Material Science within the Web-Based Learning Module:

Cuirass (breast and back plate combination):

"Good Job! You have found the Cuirass. This combination of a breast and back plate provides protection to the central core* of the body. Like many pieces of armour, the cuirass is made of steel, which is a metal alloy. This means it is a combination of Iron (Fe) with other elements. Iron is derived from iron ore which is simply a rock containing a high concentration of iron. This ore is heated with carbon in order to eliminate oxygen molecules. The carbon interferes with the natural crystal lattice, or network of iron atoms (Fe), and acts as a hardening agent to protect against sharp and blunt trauma**. Finally, the iron is heat treated at high temperatures to remove other impurities and the end result is steel, a much stronger metal."

* "Core protection has evolved into modern day protective vests such as this camouflage bullet-proof vest and police vest. These are usually made of a material called Kevlar.
Kevlar® is a product name for a material made out of synthetic fibres of poly-paraphenylene terephthalamide. These fibres are woven together and provide protection that is five times stronger than the same mass of steel."

** "The Cuirass was advancement of an earlier form of chest protection, the coat of mail pictured here. Made up of interlocking small rings of iron, the mail is resistant to stabbing trauma, but not blunt force trauma. This means the wearer is better protected from the piercing thrust of a blade, but that the force of a blow from a weapon would still cause damage. The more rigid Cuirass can absorb and deflect much more of the blunt force, providing greater protection. "

Close Helmet:

"Fantastic! You have found the Close Helmet, also made of steel. The helmet provides rigid** defence and protection***. Specialised blacksmiths, known as armourers, made pieces of armour such as this helmet. Blacksmiths received their name from black, the colour of the metal they used, and the word smite*, which means to hit. Blacksmiths work with wrought iron because it is very easy to work with. When wrought iron is heated, it becomes flexible and more malleable."

* "The addition of carbon during armour making, not only disrupts the iron structure, but also removes gaseous oxygen. Oxygen trapped in the metal, can cause weakness, and by adding carbon in a process called smelting, the impurities can be removed."

** “This form of protection was more effective than a simple mail coif, which alone was useless against blunt trauma. Mail coifs were almost always used in conjunction with a helmet. In much the same manor as the Cuirass, the strong steel prevents direct absorption of blows to the head. Other forms of protective helmets are this helmet a crusader might have used and the pot type helmet.”

*** “The need for head protection is essential in many modern day occupations. These include military helmets such as this camouflage helmet for an infantry soldier. Another example is this policeman’s helmet that provides protection and signifies authority. The defence of the brain is vital to surviving head trauma, whether purposeful or accidental.”

Open Ended Question: What protection does the head natural possess?

Greave and Sabaton:

“Great! You have found the Greave and Sabaton. This amour is for leg protection, and is a development from simple mail protection. With a melting point of approximately 1350-1460 degrees Celsius (dependant upon the percent of carbon present), the wearer is likely to perish before the armour is affected!”

Gauntlet:

“Excellent! You have found the Gauntlet. This piece of armour was used for hand protection**. Made of steel it demonstrates the technique of articulation, which is the connecting of smaller pieces of steel with simple rivets. These plates increase the risk of rust*, because water can be trapped in the joints. The advantage is that articulation allows for a wider range of motion.”

* “Rust, also called oxidation, is an important consideration when trying to preserve armour. If steel comes into contact with water when oxygen is present, a permanent change occurs. This reaction leads to the formation of rust. Basically this reaction can be written as:

Iron + Oxygen -> Iron Oxide

The iron and oxygen are the reactants and the iron oxide (rust) is the product. The following shows the reaction using the chemical symbols.”

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

If iron is underwater and does not come into contact with air, it will not rust as quickly. This shows the need for oxygen in this process.

(more)
Open Ended Question: How can we prevent iron from rusting?

If you wish to learn more about elements and their properties *click here* for the periodic table of elements.

** “Modern day warfare has decreased the need for hand protection. However, many sports still require athletes to use hand protection. These kendo gloves protect the combatants from injuring their hands during contests.”

Kite Shield:

“Splendid! You have found the Kite Shield. Composed of wood, iron, and leather this triangular shield was popular in the 11th Century, when the White Tower was built. It was used to parry blows and protect a soldier to compensate for the lack of extensive armour, which was not readily available in the 11th Century. The combination of these materials was designed to provide a large degree of hardness. Hardness is a characteristic of a solid material and is a measure of how much it can withstand before its shape is permanently changed.

(more)
Another type of shield is the round shield appearing below. It was a much more popular shape for a shield during the first millennium. The kite shield evolved from this design to protect a larger area of the body (including the legs). The round shield was constructed from a mixture of linden (lime wood), alder, and poplar woods because they are not dense and are light to carry. These types of woods were also popular because they were not inclined to split like oak and they were some of the most common trees in England.”

(more)
Modern day examples of the hand held defence shield is a riot shield used by police for protection during riots.

Broadsword:

“Awesome! You have found the Broadsword. This was the most common type of sword used during the Middle Ages. The steel used was of the strongest variety produced because it needed to withstand a large amount of stress*. There are many variations on this type of sword including the Schiavona, which has an extensive hand guard. Although the military role of swords was gradually replaced following the invention of the gun, modern examples exist such as this fencing sword.”

* “Stress is the amount of force applied to an object. There are many different types of stress dependant upon how the force is being applied. For the sword to

be effective it must be able to cause an impact repeatedly from many angles without breaking, and therefore must be comprised of the highest grade steel."

Bow and arrow:

"Well done! You have found the Bow and Arrow. This weapon was more effective when used from a protected position and in large numbers. The bow's function is based upon the fact that it can be used to store energy (elastic potential). This is possible because the bow material has significant tensile strength*.

(more)
This projectile system was eventually replaced following the invention of gun powder** by the Chinese between the 7th and 9th centuries. Gun powder was eventually used in a long-arm much like this one."

* "Tensile strength is the amount of *stress* that can be applied to the side of an object before it is permanently changed. The bow had can handle a large amount of tensile stress and this resistance to deformation transfers force into the projection of the arrow."

** "Gun powder is a fast burning substance that releases large amount of gases when it is ignited. This means that the solid is converted to a gas, containing the same number of molecules, with much more space in between them. When lit in a confined space, such as the chamber of a gun, the rapid gas expansion increases the pressure in the barrel, pushing the bullet out at incredible speed. Today this system has been advanced into self-containing bullets where the powder is encased around each bullet jacket and no longer requires a separate charge."

Vambrace:

"Splendid! You have found the Vambrace. This is armour that is jointed to protect the elbow and allows for movement of the arm. The strength of the steel is related to its density. As the density of a metal increases, so does its strength. The metal will also become heavier as the density increases, which can be very impractical for a knight to wear. Density is the amount of matter that is contained in a certain volume."

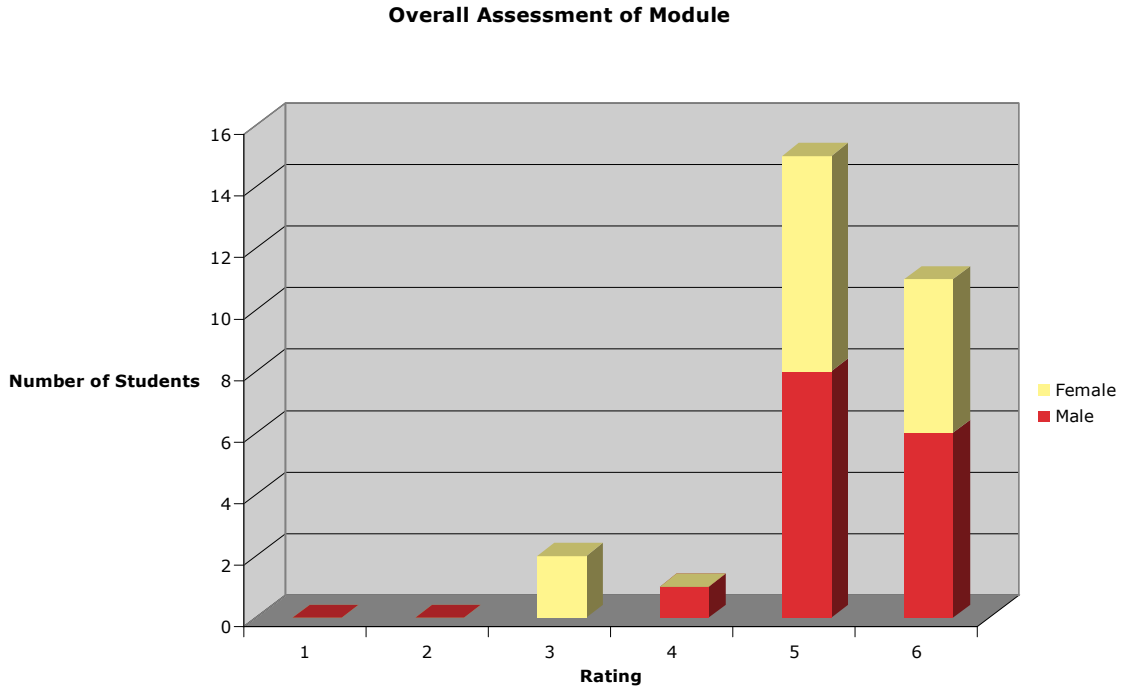
Density = (mass/volume)

(more)
Open Ended Question: Which is heavier, a tonne of feathers or a tonne of lead?

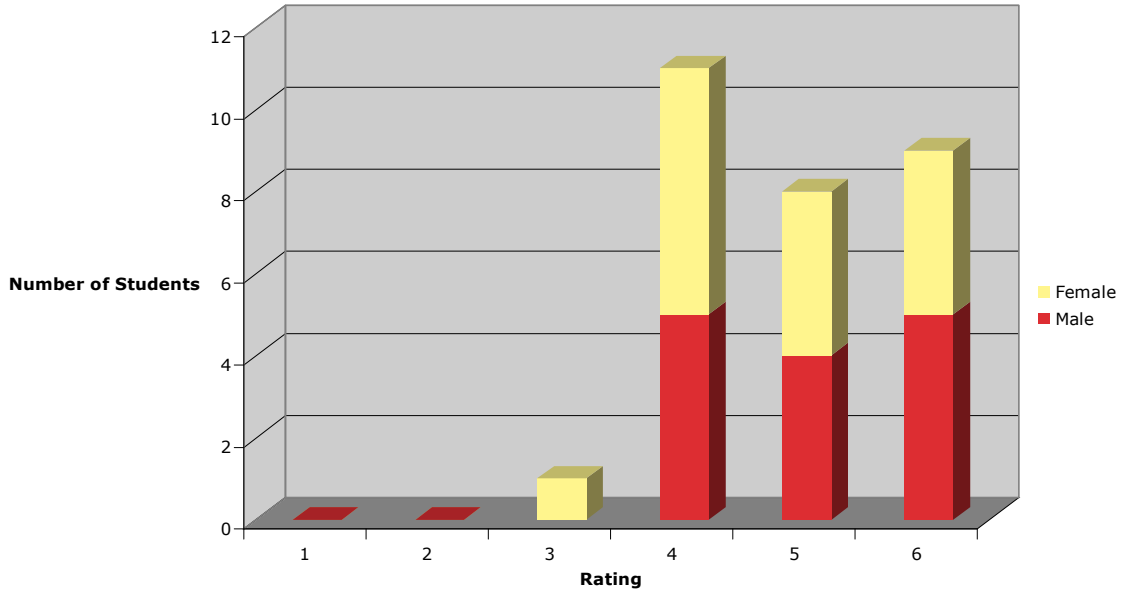
Open Ended Question: Which of these 2 materials has a greater density?

APPENDIX F: Assessment Survey Data

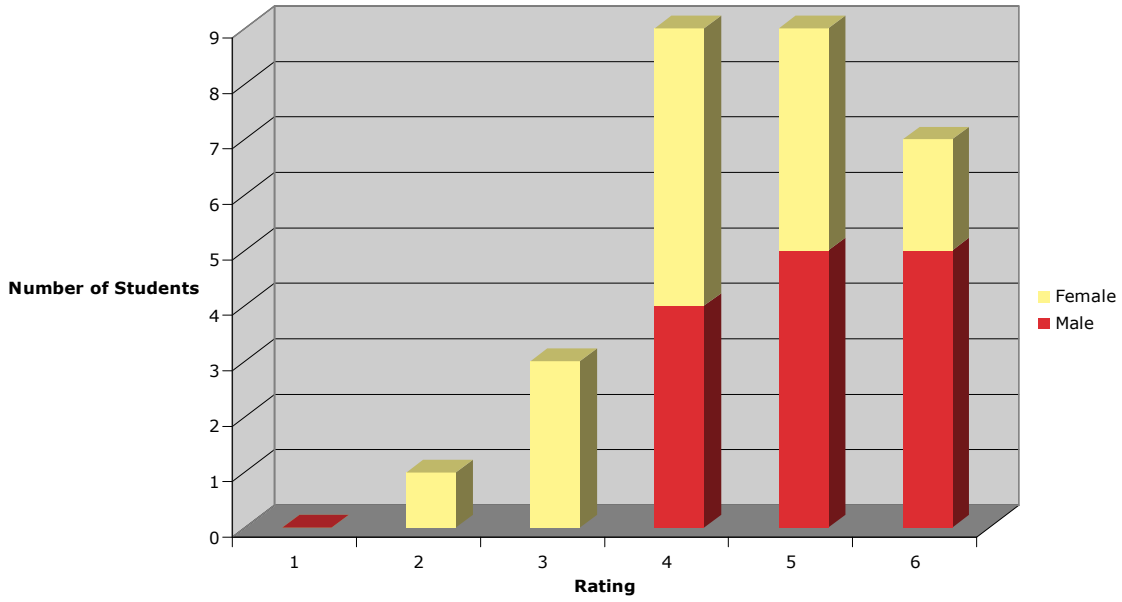
	How fun was the *Mystery at the Tower?*	How helpful was the *Mystery* in learning material science?	How easy was the *Mystery* interface to use?	How challenging were the clue questions in the *Mystery*?	How challenging were the questions in the *Detective's Notebook*?	Overall
AVERAGE	4.8	4.6	4.6	4.4	4.9	5.2
ST. DEV.	0.9	1.1	1.3	1.2	1.0	0.8
MEDIAN	5.0	5.0	5.0	4.0	5.0	5.0
MODE	4.0	5.0	6.0	4.0	5.0	5.0
RANGE	3.0	4.0	5.0	5.0	4.0	3.0



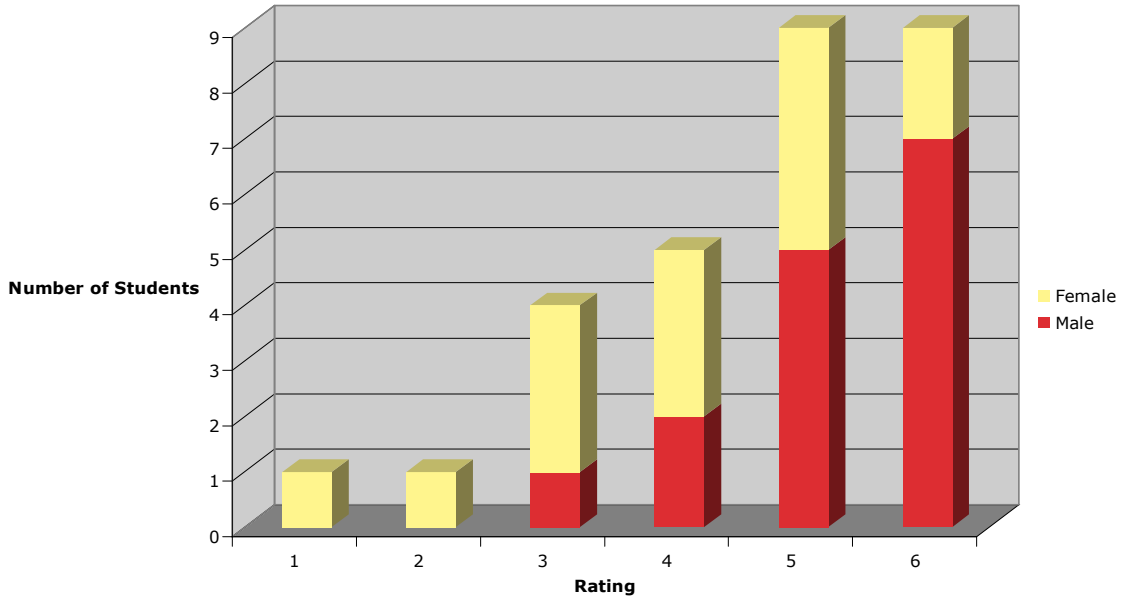
How Fun was the Mystery?



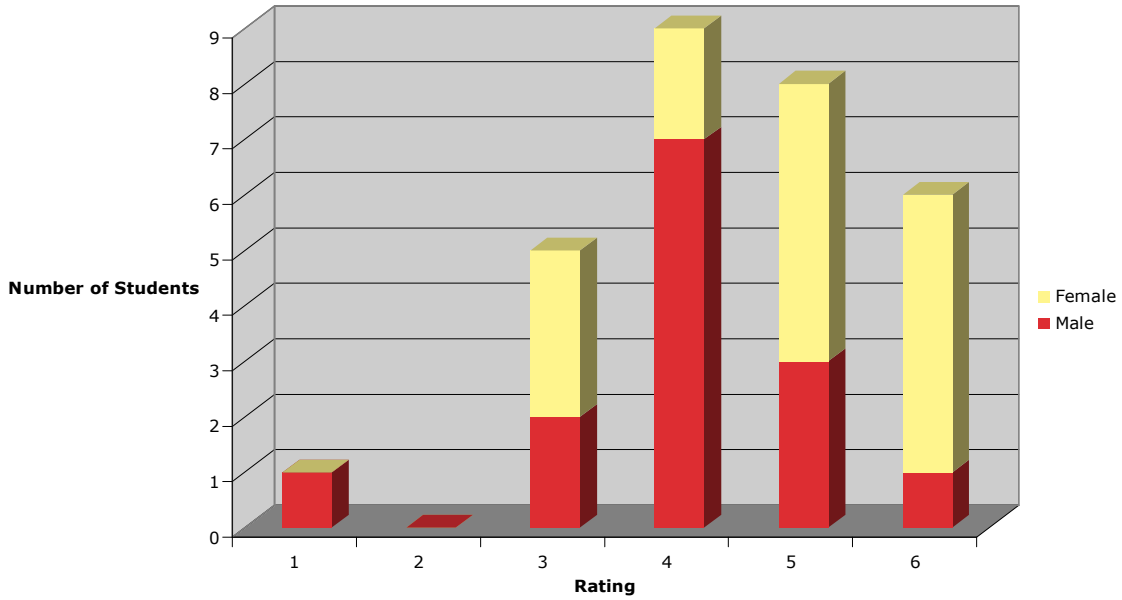
How Helpful was the Mystery for Learning?

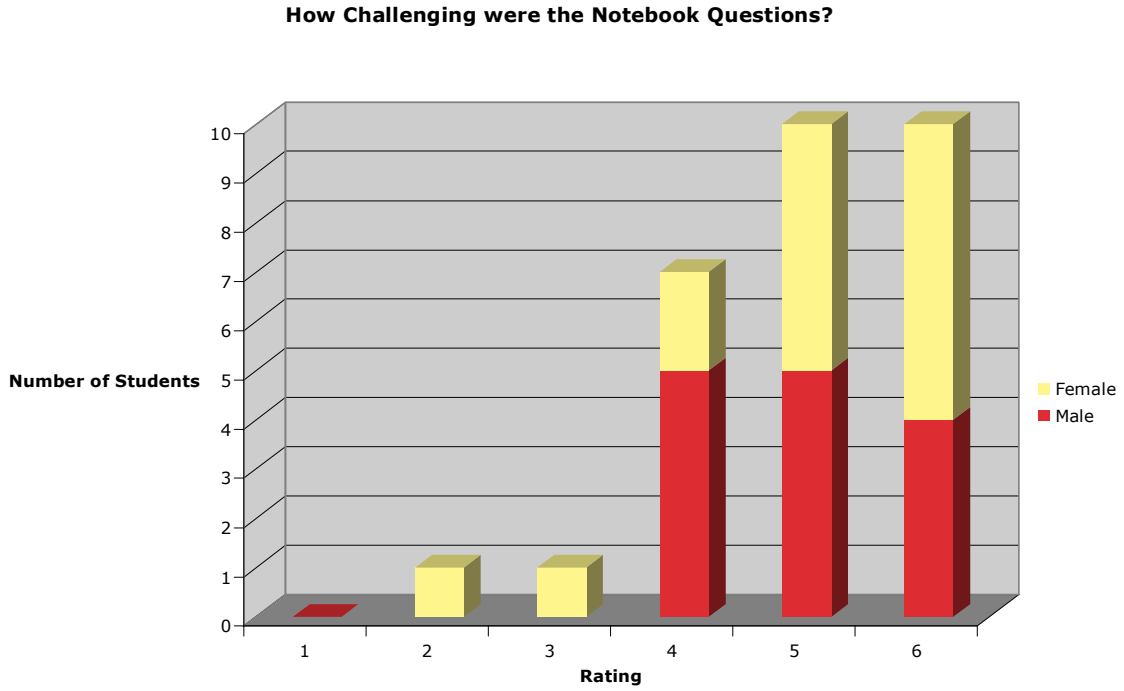


How Easy was the Interface to Use?



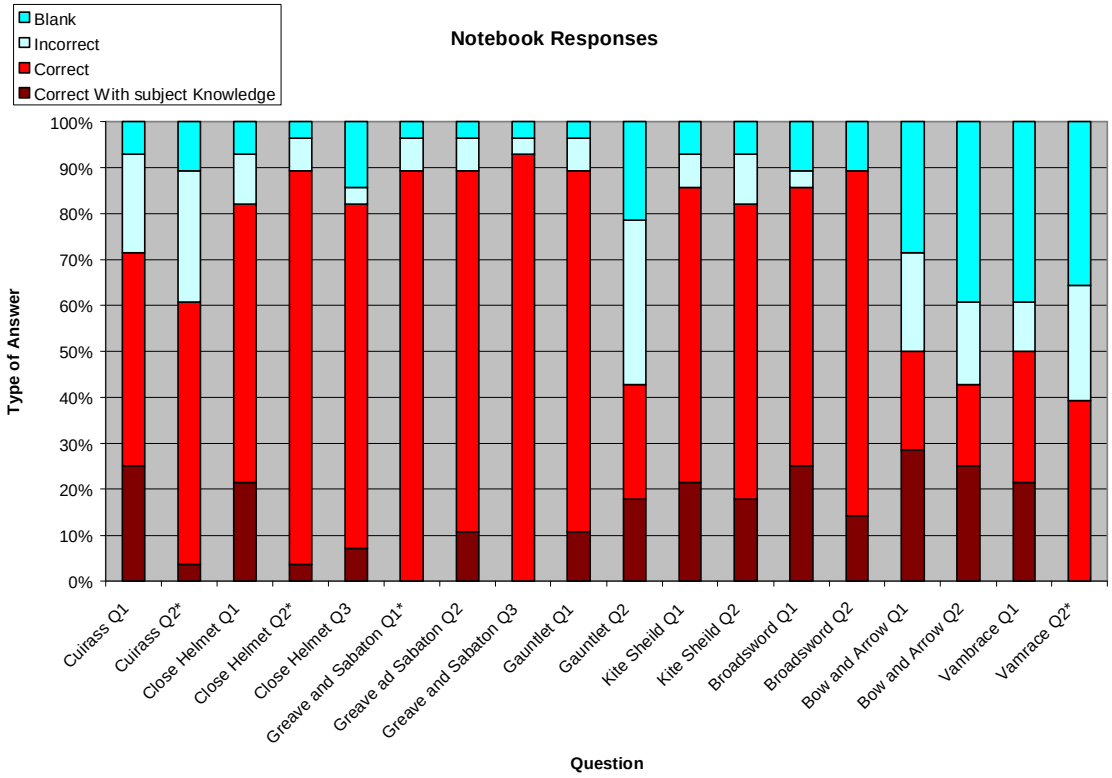
How Challenging were the Clue Questions?




How Challenging were the Notebook Questions?
Number of Students
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
Rating
Female
Male

APPENDIX G: Completed Detective's Notebook Data

Percent Correct	Percent Incorrect	Percent Blank	Question
71%	21%	7%	Cuirass Q1
61%	29%	11%	Cuirass Q2*
82%	11%	7%	Close Helmet Q1
89%	7%	4%	Close Helmet Q2*
82%	4%	14%	Close Helmet Q3
89%	7%	4%	Greave and Sabaton Q1*
89%	7%	4%	Greave ad Sabaton Q2
93%	4%	4%	Greave and Sabaton Q3
89%	7%	4%	Gauntlet Q1
43%	36%	21%	Gauntlet Q2
86%	7%	7%	Kite Sheild Q1
82%	11%	7%	Kite Sheild Q2
86%	4%	11%	Broadsword Q1
89%	0%	11%	Broadsword Q2
50%	21%	29%	Bow and Arrow Q1
43%	18%	39%	Bow and Arrow Q2
50%	11%	39%	Vambrace Q1
39%	25%	36%	Vamrace Q2*
73%	13%	14%	Total
		29%	% Wrong due to time constraints



APPENDIX H: Teacher's Self Assessment Survey

Please take a few minutes to answer these questions about the learning module, and provide any general comments or suggestions that you may have.

For the following questions please indicate your response by circling one rating between 1 and 6, with 6 being the best.

1. How appropriate was the content presented in the module?
   1 2 3 4 5 6
2. How appropriate was the difficulty of the material presented in the module?
   1 2 3 4 5 6
3. How well do you feel that the students learned material science concepts?
   1 2 3 4 5 6
4. How easy do you feel that the module was for students to use?
   1 2 3 4 5 6
7. How well do you feel that the module addressed the curriculum requirements?
   1 2 3 4 5 6
5. How would you rate the entire educational experience?
   1 2 3 4 5 6
6. How easy was the *Teacher's Guide* to use?
   1 2 3 4 5 6
8. Would you consider using a module such as this for other subjects?
   Yes No
9. How would you rate the ease of uploading the module for students to use?
   1 2 3 4 5 6
10. Would you suggest any changes for the learning module?