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Material Science Website for the Royal Armouries Museum at HM Tower of London

Sponsored By:
Royal Armouries Museum

Submitted To:
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Abstract

The Royal Armouries Museum's Education Centre at the Tower of London offers programmes in the subjects of history and science. The Education Centre is not satisfied with the limited number of visits from secondary school classes to their material science programmes. The purpose of this project is to create a teaching aid for secondary school teachers/students to raise awareness of and to provide supplementary material for the programmes. The web-based teaching aid relates the United Kingdom's National Curriculum for science to the historical context of the Tower.

Executive Summary

The Royal Armouries Museum at HM Tower of London operates an on-site education centre, jointly run with Historic Royal Palaces. The Education Centre offers hands-on programmes to supplement a visit to the Tower. These programmes are not exclusively for students, but the lessons are tailored to the United Kingdom's national curriculum. Some of the programmes are historically orientated, while others teach material science by relating the subject to arms and armour, among other aspects of the Tower of London's exhibits.

The Royal Armouries Museum is not satisfied with the number of secondary school classes visiting for their material science programs. The Armouries' Science Education Officer, Mandy Martin-Smith, asked us to create a web-based teaching aid to entice secondary school teachers to take advantage of the science programmes offered at the Tower of London. This aid contains information about the Royal Armouries Museum's exhibits and how the collection relates to the material science portion of the United Kingdom's national curriculum. It should also inform teachers about the programmes and offer content that can be used either in preparation for or as a follow-up to a visit to the Education Centre.

Our background research began by obtaining a copy of the United Kingdom's national secondary school curriculum for the sciences. This showed us what topics schools are expected to teach, and therefore what topics should be included in our teaching tool. Our liaison with the Royal Armouries, Ms. Martin-Smith, a former school teacher, was also very helpful in telling us what level of comprehension to expect from the students we hoped to reach with this tool. She also provided us with text books that gave us a better understanding of how the subject matter is taught. Representatives of the Higgins Armories Museum in Worcester, Massachusetts, Jeffery Forgeng and Dan Nangle, were also consulted to gather insight on how other museums design their content on the web.

We decided that the most effective tool to develop for teachers is a website designed for students. We hope this website will serve many purposes. The site contains material science lessons, animations and interactive demonstrations that relate specific

topics of the material science curriculum to different exhibits one would see while visiting the Tower of London. Our hope is also that the website will show teachers that the Royal Armouries is well-equipped and capable of giving a valuable material science lesson. At the same time, the website is a tool that teachers can use to familiarize students with the topics covered in the science programmes before bringing them to the Tower of London, and a tool they can use after a visit to the Tower to summarize and reinforce the lesson. The objective here is to encourage teachers to bring their classes for a material science programme by providing useful content to supplement their visit.

A series of surveys helped in the construction of our teaching aid. Our first survey went to secondary school teachers who have previously visited the Education Centre. It asked how satisfied they are with the quality of the educational programme, how closely it relates to their curriculum and what could be done, in their opinion, to attract other schools to the Centre. A second survey went to the Heads of Science at a sampling of London area schools and almost all of England's schools with the science specialty designation. This survey asked if they are aware of the Education Centre and its programmes, what topics should be included in a web-based teaching aid and whether or not such an aid would make them more willing to visit the Tower of London and take part in an educational programme in the future.

The results of our surveys show that teachers who have previously visited the Education Centre are very satisfied with the programmes. They feel that the sessions effectively covered the material in their curriculum; they praised the quality of the staff and the hands-on aspects of the programmes. The previous visitors reported becoming aware of the programmes from past visits, from phoning the Education Centre and from the Educational Centre's brochure. This suggests that the Royal Armouries' webpage is not currently a major factor in making teachers aware of the programmes; our website is designed to change this.

Replies to the survey that we sent to the science specialist school show that, even though a few of the respondents have taken their students to the Tower of London, none of them are aware of the material science programmes offered there. This further solidified one objective of our website: to make teachers aware of the Royal Armouries Education Centre's material science programmes. The survey also shows that such a

web-based teaching aid would encourage some teachers to visit the Education Centre, further validating our efforts.

Based on all of our research, we designed our website to relate the history of the Tower of London to the National Curriculum for science. The "Armour" section of the website teaches students about atoms and elements through the use of the periodic table. It links armour to the study of metals and discusses the importance and practicality of Kevlar as modern armour. The "Crown Jewels" section uses precious gems as examples to teach students about structure, material properties and standard states. The "Distillation" section uses Sir Walter Ralegh's early experiments in the field as examples for separating substances by differences in boiling point. This section includes examples of how science is used in the production of every-day things, such as petrol and other derivatives of crude oil. The "Tensile Strength" section teaches Hooke's law and its importance in making the medieval longbow an effective weapon. Pictures of and graphs from the Education Centre's tensile strength testing machine are intended to demonstrate to teachers the quality of the facilities. The "Gunpowder" section teaches students about chemical reactions, chemical equations and conservation of matter. Animated demonstrations illustrate common reactions with which the students should be familiar.

Finally, we submitted a CD-ROM containing our website to Andy Scott, a science teacher at St. George's Middle School on the Island of Sheppey. The purpose of this trial was two-fold: to see if the website appeals to secondary school students, and to test whether or not it is useful to a teacher.

The first main goal addressed by this project is to gain a better understanding of why secondary schools are not attending the Education Centre's programmes. The second goal is to determine what kind of curriculum related topics teachers would like to see covered by a teaching aid. The third goal is to create an interactive teaching aid that is appropriate secondary school students and teachers alike.

Authorship

This project was the joint effort of Tiffany Gendall, Adrian Misiak, Jonathan Rogers and Matthew Young, four Worcester Polytechnic Institute undergraduate students. The project was completed to fulfill their Interactive Qualifying Project course requirement.

Acknowledgments

The authors would like to thank our project liaison, Mandy Martin-Smith for her supportive input during the creation of the web-based tool and her guidance while we adapted to British culture. Many thanks also to Bridget Clifford for her knowledge of the Tower of London, the Royal Armouries' Collections and history in general. We would also like to thank the rest of the Education Centre staff for accommodating us and welcoming us into their workplace, and Andy Scott for letting us test our web-tool with his students.

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1. Introduction

For centuries mankind has used museums to preserve the past for future generations. People visit these sites to admire the achievements of their ancestors and gain appreciation for their history. Many museums have taken steps to make their representations of the past more engaging to their patrons. In addition to traditional exhibits, various museums also offer interactive demonstrations, multimedia presentations for large groups, and educational programmes based on the collections. Funding for these supplementary programmes can be provided by the government, by corporate sponsors with an interest in the exhibit or by contributions from private museum patrons. Additional funding allows museums to improve the programmes and to market them to the public, which will in turn elicit more contributions.

In addition to a rich collection of artefacts, the Royal Armouries Museum at the Tower of London also offers exceptional educational programmes for teachers who bring their students into the Education Centre. The Education Centre is jointly run by the Royal Armouries Museum with Historical Royal Palaces and is located in the Waterloo Barracks Building in the Tower of London. These educational programmes teach aspects of the United Kingdom's material sciences curriculum by connecting the subject to the collections and history of the Tower of London. Since material science is not traditionally taught in a historical context, the science programmes offered by the Royal Armouries Museum may not be utilised as frequently as the historical programmes.

Despite the millions of visitors the Tower of London receives each year, it is doubtful that very many of these people are aware of the scientific significance behind each piece. The Tower of London is rich in history, but also has much to offer in the field of science. If the scientific aspects of the site are advertised to the right demographics, it should spark more interest in the scientific educational programmes. One major aspect of this project is to do just that. The key demographic reached in this endeavour is secondary school teachers, in hopes that they will bring their students to participate in the educational programmes specifically geared towards material science. By creating a material science web-based teaching aid to be included as a part of the

Royal Armouries Museum website, not only will teachers become more aware of the programmes offered about material science, but it will also help them to prepare their students for a school trip to the Tower of London and help justify the obstacles associated with transporting and funding a school trip.

The first main goal of this project is to gain a better understanding of why secondary schools are not attending the Education Centre's programmes. For instance, if the programmes are not advertised enough to teachers, or if the programmes are not well-suited to the teachers' curriculum, then these are issues that could be addressed by the Royal Armouries Museum. On the other hand, some problems dealing with transportation cost and understaffing (teachers not being able to take time out of the classroom to bring the students to the Tower of London) may be beyond the reach of the Educational Centre. However, the science education officer for the Royal Armouries museum who is also our liaison for this project, Mandy Martin-Smith, has expressed a willingness to reallocate some resources to deal with these types of problems if necessary.

The second main goal of this project is to determine what kind of curriculum related topics teachers want covered by the teaching aid. Preliminary research has shown that many of the topics explicitly stated in the United Kingdom's secondary school material science curriculum are covered in programmes run at the Educational Centre. The team, with the approval of our liaison, decided that it was best to assess the opinions of secondary school teachers to determine whether or not what they teach in their classrooms coincide with the national curriculum. Surveys of secondary school teachers were conducted to determine the most desirable content for a teaching aid.

The third, and most important, goal of this project is to design and create an interactive teaching aid that is appropriate for secondary school students and teachers alike. This web tool must appeal to students in order to be a successful aid for teachers to use in the classroom, but primarily, it must contain content that teachers want to teach.

To accomplish the three aforementioned goals, the project is split into two main phases: discovering the attitudes and needs of teachers and then using that input to create the web tool. By highlighting the aspects of the material science programmes at the Education Centre that deal with the United Kingdom's material science curriculum, the

web-based teaching tool will hopefully encourage teachers to bring their classes to the Tower of London for a unique view of science taught from a historical perspective.

Since the Education Centre is located in the Tower of London, where the students will be taking their school trip, the content in this teaching aid not only includes topics related to the Royal Armouries Museum, but also to Tower of London in general. These topics include arms and armour, longbow tensile strength, distillation, the Crown Jewels and gun powder. All of these aspects are directly linked to the secondary school curriculum on material science. There is a tensile strength lesson given at the Education Centre that uses the longbow and various bowstring materials to demonstrate Hooke's law. A famous prisoner of the Tower of London, Sir Walter Ralegh, performed some of the first practical uses for distillation, which is also incorporated into the Education Centre's lessons. By having the curriculum displayed through these traditionally historical topics, teachers will be able to prepare their students for a school trip to the Tower of London and a material science session at the Education Centre.

Past IQPs dealing with education have attempted to provide school students with informative content in a way that is interactive and appeals to younger audiences. Recently, an IQP team from WPI visited Australia with the goal of developing the educational portion of the website of the Australian Bureau of Statistics. The Australia IQP project was aimed at making web-based statistics more appealing to secondary school students and teachers (Genja, 2003). This can be used as a guideline for appealing to students via an interactive website.

The next section presents background material relating to the Tower of London, the Royal Armouries' Education Centre, educational aids, material science, and how material science is related to the Tower of London. The following section discusses the main questions that we sought to answer and the various methods we used to seek the answers. The Results and Analysis section discusses our perceived answers to those questions and how we used the answers to create our web-based teaching aid. Another short section gives some closing remarks and recommendations on how our final product could be implemented, improved, and expanded upon. Appendixes include a profile of our sponsor, copies of the surveys used to collect data, the results of those surveys, and a copy of the website we created.

2. General Background

2.1 The Tower of London

Archaeological findings have shown that people inhabited the site where the Tower of London now stands as early as the year A.D. 40. By A.D. 200 the Romans had built a great city wall, of which evidence still remains at the Tower, to protect the city of Londinium. Following the withdrawal of the Romans from Britain, the city fell into abandonment for centuries. The Tower of London was then built by William the Conqueror, after his victory at the Battle of Hastings, in the late 1070s. At that time the only building built along the old Roman wall was the White Tower, which is the central structure of the current site (Lapper, 2000). The Tower served not only to protect London itself, but also to serve as a sign of William's power over his subjects (Loftie, 1886). Over the years, surrounding walls and towers have been added to the site such that the plan of the Tower of London is now that of a concentric castle. The White Tower stands in the middle of the complex, surrounded by other buildings and an inner wall of towers. Another outer wall with towers and battlements line the border of the buildings and inner towers. Previously, the Tower of London was located directly on the Tames River, but during the reign of Richard II, a wharf was built to separate the Tower from direct contact with the Thames River (Lapper, 2000). There was also a moat around the site, which has been drained and filled due to sanitation issues.

Over the years, the Tower of London has served many purposes. It has been a home for monarchs, a prison for enemies of the state and it is the site of several notable executions. Despite its designation as a Royal Palace, more suitable lodgings at other sites made the White Tower a less desirable place for the monarch to reside. The Tower has served as a prison for notable traitors of England, and has served in this capacity until as late as World War II. Despite the well-known reputation of the Tower as the site of torture, some well-to-do prisoners who were still in the Crown's favour were given quite comfortable accommodation. Parts of the castle were modified to make lavish lodgings for some prisoners, and the families of prisoners were even allowed to live in the same

quarters. Some of the notable condemned at the Tower of London, like Anne Boleyn, were beheaded using the block and axe. This relatively quick and merciful fate was undoubtedly better than other methods of capital punishment employed at the time. However, some prisoners received no special consideration and were tortured to extract information or confessions from them (Bridget Clifford, personal correspondence).

Today the Tower of London, run by an organisation called Historic Royal Palaces, draws a great number of visitors. One of the biggest attractions at the Tower of London is the famous Crown Jewels, also known as the Royal Regalia. These fine pieces are used in the British coronation ceremony (Loftie, 1886). During the English Civil War most of the Regalia was destroyed or lost, but new pieces were created at the time of the Restoration. These are now displayed in the Jewel House, a part of the Waterloo Barracks building.

There is also a nightly ritual called the Ceremony of the Keys, in which the gates of the Tower are locked until morning. This ceremony has been held every night for over 700 years. The White Tower is also home to the Chapel of Saint John the Evangelist, a Normal chapel that is still in its original condition. Another chapel, The Chapel of Saint Peter, is also part of the Tower of London.

Because the Tower has been deeply embroiled in the affairs of royalty and enemies of the state alike throughout the centuries, every part of the site is rich in history. For this reason, most people tend to associate the site with history. It is the goal of this project to make people, specifically secondary schools teachers, aware of the science education opportunities presented at the Tower of London.

2.2 The Royal Armouries Museum

The Royal Armouries Museum is an organisation dedicated to preserving and displaying England's historic arms and armour. It has branches throughout the United Kingdom in HM Tower of London, Ft. Nelson, and Leeds and a new (May 2004) branch in the United States in Louisville, Kentucky. The collections housed at the Tower of London are displayed in the historic White Tower. Despite this fact, the Royal Armouries Museum has no claim to the Tower of London site or even the White Tower itself. These are both owned by the State and run by Historic Royal Palaces. In effect, the Royal Armouries Museum is merely a tenant at the Tower of London. Most of the Royal Armouries Museum's collection is housed in Leeds, but some of the most well-known pieces are displayed at the Tower of London due to the historical importance of the site, the massive amounts of visitors who visit there and because many of the pieces in the collection were originally housed at the Tower.

The collection of the Royal Armouries Museum is to a great extent credited to Henry VIII, who was an armour enthusiast and kept his collection at the Tower of London. His collection, which was inventoried after his death in 1547, was the basis for the exhibit shown in the Tower of London today (Dufty, 1968). Unfortunately, the collection does not include many items from before the time of Henry VIII since he discarded most of the old equipment in favour of newer arms and armour. However, just as English monarchs added to the structure of the Tower over the years, they also added to the collections of the armoury.

The value of the Royal Armouries' collection at the Tower of London for teaching history cannot be disregarded. It features pieces that show visitors a visual representation of English martial and political history. However, the Royal Armouries Museum has enhanced the educational value of its collections beyond mere viewing and reading of artefact descriptions. The Royal Armouries Museum has had an education department for about 30 years, teaching students about history and science through hands-on interaction. This aspect of the organisation is not widely known by visitors because its Education Centre is located away from the collections in the White Tower, in an area of the Waterloo Barracks that is not accessible to the average visitor.

2.3 Secondary Schools

The United Kingdom's schools can be classified into two main categories: state schools and public schools. Public schools (also known as "private" or "independent" schools) are schools that one must pay to attend. State schools, on the other hand, are free to attend and are funded by the government. The most broad-based of these state schools is the comprehensive school. These generally co-educational schools have no entry system, and students normally attend the school specific to where they live. The comprehensive school is analogous to what is known as public school in America. Another type of state school, the maintained school, is different from the comprehensive school in that it has a board of governors who exert some decision on which students attend. A foundation school has a board of governors, and, like a maintained school, exerts some control over accepting students. However, the foundation school is usually run by some religious or charitable organisation which is represented on the governing board and has control over hiring and other administrative decisions. While state-funded, these schools can also derive extra funding from the foundation that runs them. Grammar schools are state schools that are co-ed or single-sex. These schools typically use an entrance exam such as the *11+ Exam* to select students.

Some schools specialize in certain areas, such as arts, science, technology etc. City Technology Colleges are state schools that focus in computer technology studies. They have improved facilities and often receive corporate sponsorship. One type of school that we focussed on in this project is the science specialist school. These state schools have to meet certain criteria in their curriculum to gain the science specialist status. These schools often share their skills amongst each other. We directed our surveys primarily at England's science specialist schools because we felt they would be more interested and willing to devote resources to visiting the Tower of London for science related purposes.

British students attend primary and secondary schools and then college before moving on to a university (if they choose to do so). Early education is broken down into levels or key stages (KS). KS1 is the beginning of primary education, which children enter at the age of 3 or 5. Following KS1, students move on to KS2; this comprises their

studies from about ages 7-11. KS3 is generally taught to children aged 11-14. KS4, which students leave around age 16, is the last level of formal education before college. Late KS1 and all KS2 students are generally put under the umbrella of primary education. KS3 and KS4 are collectively referred to as secondary education (National Curriculum, 2004).

The government mandates a standardized test for students each year. These tests are called performance tables. Although a student may not pass these levels, it will not affect their acceptance into the next grade. Each year of education contains students within a range of levels, but usually students are expected to achieve a certain level by the end of each year. The levels are used as a benchmark to compare schools, districts, and individuals (Department of Education and Skills, 2004).

2.4 Material Science

The United Kingdom's National Curriculum covers a wide range of material science topics. Teachers use the periodic table of elements to teach students about atoms and the traceable pattern of elemental properties. A period consists of the elements in the same row across on the periodic table. The first two columns on the left and the last six columns on the right are known as groups. The ten columns between these groups are known as the transition elements. Each group consists of the elements of that column. The groups and periods of the periodic table can help to predict atomic trends. For example, the atomic radius (the size of the atom) increases as one progresses down each column or from left to right in each row (Acaster, 1993).

The periodic table shows other properties of elements. The atomic mass is the mass of a single atom of an element. The atomic number of an element refers to the number of protons (positively charged particles) in the nucleus of the atom. Since atoms are neutral, it follows that each element contains the same number of electrons (negatively charged particles) as protons. The oxidation state of an element is a positive or negative integer that is related to the number of electrons surrounding the nucleus of the atom and is important for predicting the behaviour of the element in chemical reactions (Acaster, 1993).

Elements of the periodic table are divided into categories based on their properties and behaviours. Reactive metals are found in Groups I and II, which are known as alkali and alkaline metals, respectively. Alkali metals have a +1 oxidation charge and have very similar reaction behaviours. Alkaline metals have a +2 oxidation state and also share similar reaction behaviour. The transition metals are found in columns 3-12 of the periodic table. These elements can have multiple oxidation states and contain the familiar metals. Iron, for example, can have an oxidation state of +2 or +3. Poor metals, or metalloids, have some properties of metals and are located to the left of the dark line through Groups III-VI. To the right of this line are the non-metals. These elements are brittle, do not conduct electricity well and are common components of most organic chemistry reactions. The halogens, the elements of group VII, all have an oxidation state of -1, and are some of the most reactive of all the elements. On the other hand, the inert

gases are located in the last group and are non-reactive elements. They have filled the electron cloud surrounding their nucleus so they are unwilling to accept or provide electrons in a chemical reaction. An electron cloud is the area of the atom where electrons spin around the nucleus and a nucleus is the centre part of the atom made up of neutrons and protons (Acaster, 1993).

Atomic properties are responsible not only for reactivity behaviour, but also for the physical properties of the elements. These properties include structure, density, malleability, ductility, hardness, melting point, boiling point, appearance, standard state and metallic vs. non-metallic. A material's structure is the way its atoms are arranged and organised to create the substance's three-dimensional configuration. The density of a substance describes the amount of matter per unit volume of the substance and is defined by dividing its mass by its volume. A material is said to be malleable, or have malleability, if it can be hammered into thin sheets. The ability of gold, one of the most malleable substances, to be made into gold foil is an example of this property. A material is said to have ductility, or to be ductile, if it can be pulled into long thin wires. Copper's ductility and ability to conduct electricity make it a very useful material for making wires (Acaster, 1993). The property of hardness is relative to a scale (called the Moh's scale) that measures how easily the material can be scratched by other materials. For example, talc is the virtually the softest material and can be scratched by anything, while diamond is the hardest known substance (Moh's Scale of Mineral Hardness, 2005). Melting point is the temperature under normal atmospheric conditions, at which a substance changes from its solid state to liquid state. On the other hand, boiling point is the temperature at which a substance changes from its liquid to its gaseous state. A substance's colour, texture and odour are all used to describe its appearance. A material's standard state is the naturally occurring state of the material at 25° C and 1 atmosphere of pressure. A material is said to be non-metallic if it is brittle, dull and does not conduct electricity well. Metals are also good conductors of electricity and heat, and are also very malleable and ductile (Acaster, 1993).

Distillation is a process through which two or more different substances in solution can be separated based on their physical properties, specifically their boiling points. Generally, distillation entails the boiling of a solution to create vapours, and then

the cooling of the vapours to condense them, thus yielding the purified solute or solvent. This process takes advantage of substances having different boiling points, so as temperature of the system is increased, the different substances vaporise in turn (Acaster, 1993). Crude oil is used to render many important products using a technique called fractional distillation. Fractional distillation is used when dealing with an aqueous solution of two or more different compounds with different boiling points. Large distillation columns are separated into layers by a device called a bubble cap. These bubble caps allow liquid to flow down the column while mixing with the hot vapours that are travelling up the column. The temperature of the column decreases from bottom to top. Therefore, the compounds with the lower boiling points are separated at the top of the column and those with higher boiling points are kept the bottom (Bloomfield, 1991).

The national curriculum states that students should have an understanding of Hooke's law. Hooke's law states that when a force is applied to a spring, the change produced is proportional to the applied force. An object obeys Hooke's law if it is elastic and stretches (or compresses) evenly with force, that is, if the change produced is proportional to the applied force (Bloomfield, 1992). Hooke's law can be used to demonstrate the tensile strength of materials, such as the longbow, Kevlar, hemp rope and regular string. A tensile strength testing machine can be used to measure the force required to produce an equivalent change in each material to show which one is stronger. Testing can show that the hemp used to string a longbow has high tensile strength and will not bend with the bow, which would dampen the elastic force transferred to shooting the arrow (Bickerstaffe, 1999).

A chemical equation shows what reactants are being used in a reaction and what the final products of the reaction are. In a chemical equation the reactants are written first followed by an arrow which tells the direction of the reaction. The products are written on the right side of the arrow. In order to write a correct chemical equation, the number of atoms of each element needs to be the same on the left and right sides of the arrow. This is required to by the law of conservation of atoms, which states that in a chemical reaction, no atoms are created or destroyed, just rearranged in a different form. If the basic formulas of the reactants and products do not have equivalent numbers of each type of atom, prefix numbers can be added to the necessary molecules to denote that

number of molecules is used/produced in the overall reaction. The process is known as "balancing" the equation (Kitagawa-Deleon, 2005).

There are six basic types of chemical reactions: synthesis, decomposition, combustion, single replacement, double replacement and acid/base. A synthesis reaction occurs when two or more substances combine to form a more complex one. A decomposition reaction occurs when a compound breaks down to two or more simpler parts. A combustion reaction is any reaction that gives off heat as a product. A single replacement reaction occurs when a single element takes the place of another element in a compound. Likewise, a double replacement reaction involves two compounds that exchange elements to form two new compounds. In this reaction two reactants yield two products. Finally, an acid/base reaction is a special kind of double replacement reaction that occurs when an acid and base react. The H^+ ion (a proton, represented as a hydrogen atom that has been stripped of its electron) from the acid reacts with the OH^- (hydroxide) ion from the base to form water (Kitagawa-DeLeon, 2005).

2.5 Material Science at the Tower of London

Materials science is an integral part of the United Kingdom's curriculum at all levels. As early as KS1, students begin to learn about materials, their properties, their various uses and how they can be changed by means such as heating or forming.

The subject of material science is stressed by the Royal Armouries Museum's Education Centre because of its important role in the history of armour and armament. For example, one of the programmes offered at the Education Centre deals with medieval armour and relates its fabrication and composition to modern armour such as Kevlar. Another comparison is also made to modern protective sports equipment. In addition, the educational department highlights early distillations experiments that were carried out at the Tower of London. Students can learn about material science as it pertains to weapons-building by using a tensile test to calculate the strength of the longbow, a common medieval weapon. The Tower of London itself is a useful aid in teaching students about the materials of building, like stone, and the strength of such materials.

Sir Walter Ralegh, one of the more famous prisoners at the Tower of London, was a pioneer in the process of distillation. He actually performed distillation experiments at the Tower in attempts to purify drinking water. The Education Centre uses the distillation experiments carried out at the Tower by Sir Walter Ralegh as a context to teach students about purifying or separating substances based on differences in boiling points. Students are taught that he purified his drinking water by boiling water and condensing it to remove salts, dirt and other impurities that boil at higher temperatures than water. Furthermore, the Education Centre demonstrates and discusses the science behind the strength of a long bow. A machine is used to demonstrate Hooke's laws and to test the tensile strength of a few different long bow samples, certain woods and other materials, like Kevlar. These education programmes are prime examples of topics directly related to science that we hope to bring to the attention of secondary school teachers.

2.6 Educational Aids

The internet has brought forth a revolution in the way people communicate across the globe. This revolution in information sharing has had a significant impact on learning in the classroom. In countries across the globe, schools have been working to bring the internet into their classrooms, realizing the potential for such a powerful source of information and collaboration. The internet has even made it possible for whole classes to be taught and administered entirely online.

The Royal Armouries Museum asked us to produce a teaching aid based on the collections of the museum and to relate them to the UK curriculum for material science. The project liaison, Mandy Martin-Smith, stated that the teaching aid should be web-based as well as appealing to both teachers and students. The goal is to create a tool which is easily accessible to secondary schools and which makes them aware that science is taught at the Museum. The Museum hopes that this project will encourage more secondary school teachers to bring their students to its facility for educational school trips.

Since this teaching aid deals with the sciences, it is important that the information displayed is consistent with the principles of science laid forth in the United Kingdom's curriculum. Theory and experimentation are key parts of this curriculum. Students learn best when they become the scientist and can learn through first-hand experience (Duschl, 1990).

> The interactive potential of the computer is one of the principal reasons it is used as a medium for instruction. In computer-based instruction, learners actively participate in the learning process: they are presented with an array of choices from which to construct their own path to knowledge and understanding (Horton, 2000).

The project liaison has confirmed that internet access is not available in every secondary school classroom, but most every secondary school does have an IT suite in which students can use the internet to complete tasks related to the curriculum. Students may also have internet access in their own homes. Even though the aim of this project is to present teachers with material for their students, it should also be useful for students who are casually browsing and do not have a teacher to guide them through the learning

experience. At the same time it should grab their attention so they will want to explore and learn more about the information provided for them.

Several options for web aids can be explored. PowerPoint presentations can be uploaded on a website for students to access. PowerPoint slides can be used for lectures and also include multimedia such as images, video and audio. Multimedia is one of the most important advantages of a web-based tool. By relating information via multimedia the student can choose how he or she wants to gather the material. Simulations may also be another option. Simulations provide an interactive way of looking at the world and are an "excellent teaching tool: they allow students to explore different scenarios and observe and analyze the outcomes" (Horton, 2000).

From past IQP projects, especially the *Web-Based Statistics Education for Schools* project which was completed in Australia in 2003, there is already information gathered about what makes a successful web tool. The outcome of this IQP helped to make the Australian Bureau of Statistics website more interactive, informative and appealing to secondary school students and teachers by taking surveys and discovering what qualities are important to the user. These qualities include: user interactivity, challenging to students, complimentary to school lessons, computer exclusivity, sound and colour (Genja, 2003).

A web-based tool is a convenient and practical solution for teachers and students alike. Students can learn required material in an interactive manner. Teachers, on the other hand, can use this technology to their advantage by using the internet to ease their workload and to stimulate their students' interest in learning.

3. Addressing the Issue

The methods employed for this research project are a mixture of qualitative and quantitative research. Initially, research was conducted to gather data about the United Kingdom's secondary school curriculum. Our review of the curriculum provided essential information to help the team ask appropriate and informed questions to teachers about what would be useful in creating a teaching aid. This method is qualitative, while our other main method, sampling through surveys, is quantitative. Interviews were conducted in Worcester and subsequently surveys were carried out in London in order to gather information about other museums' approaches to school trips and to gauge teachers' feelings towards an interactive web tool.

The main questions researched included: "How do the collections at the Tower of London relate to the United Kingdom's secondary school material science curriculum?", "How do other museums encourage teachers to arrange school trips?", "Are teachers aware of the educational programmes offered at the Royal Armouries' Educational Centre?", and if they are, "Why do teachers choose not to bring their students to the Education Centre for school trips?" We also asked teachers what they would find useful in a web-based tool and what secondary school children would find informative and interesting in a website. Their responses were essential to creating what we believe to be an effective teaching aid.

Knowledge of the United Kingdom's curriculum was used to link specific aspects of the collections at the Tower of London to the topics that teachers are expected to deal with in their classrooms. Reviewing how other museums have attracted secondary schools for school trips provided the team with ideas of what schools can expect to learn from such a trip. Finding out if teachers are aware of the educational programmes offered at the Royal Armouries Museum helped to determine the scope of the problem--whether the Educational Centre needs to improve the programmes or needs to better inform schools about the programmes. The intended use of the proposed teaching aid is for students to explore and learn from the web page while teachers instruct from their own lesson plans. For this reason it was imperative to not only know what teachers

intend to teach, but also what will grab the attention of school children and help them become interested in learning about material science. We also thought it would be useful to ask secondary school teachers who have previously visited the Educational Centre about their impressions and the impressions of their students.

The following subsections describe how our interviews and surveys were conducted, what specific issues we hoped to have addressed and how those issues related to the creation of our web-based teaching aid.

3.1 The Education Centre and the National Curriculum

Our liaison with the Royal Armouries Museum, Mandy Martin-Smith, provided us with a copy of the United Kingdom's science curriculum. We focussed on the material science topics covered in Key Stages 3 and 4, the secondary school years.

The Royal Armouries Museum collections housed in the White Tower, as well as other aspects of the Tower of London, provided a wide-ranging array of subjects from the curriculum to include in the teaching aid. The topics of chemical reactions, phase changes, properties of metals and crystalline structure were researched in relation to cannon and gunpowder, Sir Walter Ralegh's distillation experiments, metal arms and armour and jewels at the Tower, respectively.

A literature search was the basis of all the research conducted for this aspect of our work. The United Kingdom's National Curriculum, contains concrete and standardized guidelines about what should be taught. These documents were reviewed and used to create content for the web-based tool, as well as to form educated questions that were asked in surveys to secondary school teachers. These same questions were also useful for interviews with museum staff.

Surveys addressed to the heads of science at science specialist and London area schools inquired about the topics they taught in their material science curriculum. These surveys, as well as the cover letters explaining our project to the teachers, can be found in Appendix B. Survey responses (all of which are shown in Appendix C) showed that a great portion of teachers follow the curriculum very closely when making lesson plans. From these surveys and from records of previous visitors kept by the Educational Centre, interviews were arranged to speak with teachers that we believed could provide useful, in-depth information about what they teach their students about material science. Surveys sent to previous visitors of the Education Centre asked teachers how closely the programmes followed their curriculum. We also asked the teachers for their input on content for a web-based teaching aid.

3.2 Encouraging School Trips

Finding out how other museums attract secondary schools is a great way to gain insight on how to encourage teachers to take their classes to the Tower of London Education Centre. Prior to our work in London, we contacted the Higgins Armory Museum in Worcester, to find out how they conduct school trips, how they encourage schools to visit their museum for school trips and what early-teenaged students find most interesting about the exhibits. Interviews were set up with the museum staff, one with the curator of the armour collections and one with a tour guide, to ask questions about how they attract schools to their site. We also thought it would be useful to find out how they relate the content of their exhibits to the schools' curriculum. This is relevant because the Higgins Armory and the Royal Armouries feature similar exhibits.

The first interview was with the curator of the arms and armoury collections, Jeffery Forgeng, who is also a humanities professor at WPI. Research prior to the interview indicated that Professor Forgeng has sponsored IQPs for WPI in the past at the Higgins Armory. Some students he supervised created an interactive web tour for people who are interested in visiting. The questions prepared for this interview queried his thoughts on how to encourage schools to visit by using a website as an advertising tool, and whether he had any advice for this project. We also asked questions about how to relate the United Kingdom's curriculum to the collections at the Tower of London, and other ways that the Higgins Armory encourages schools to visit their museum.

Professor Forgeng recommended that we speak with the Armory's education officer to gain more insight on how to encourage school trips. We scheduled an interview with the education officer, but they were unable to attend. Tour guide Dan Nangle filled-in and was able to answer all of our questions. Mr. Nangle related to us that the Armory obtains lists of teachers in the area and sends letters to inform them that the museum tours are tailored to Massachusetts standardized testing. Information about what children particularly like about the exhibits and how information should be presented to them was recorded and proved to be useful in the planning stages of this project.

Additionally, online searches of the Higgins Armory's website and other interactive websites provided us with some ideas. Professor Forgeng told us that he believes their interactive site indisputably attracts teachers and students to visit the Higgins Armory. This interview confirmed that we should design an interactive website as a teaching aid to attract both teachers and students alike to the Royal Armouries' Education Centre.

3.3 Gauging Teachers' Awareness of the Education Centre

Asking secondary school teachers what level of awareness they have of the Royal Armouries Museum provided a basis for understanding why they do not take their classes there for school trips. If teachers are unaware of the material science programmes offered at the museum, this indicates efforts should be aimed at raising awareness through the internet and other appropriate media. If teachers are aware of the programmes, yet still do not take advantage of them, this indicates that the teachers feel the programmes would not be a worthwhile for a school trip.

Teachers' awareness of the programmes was assessed by using surveys. One set of surveys was faxed directly to 38 teachers who have previously taken their students for a session at the Education Centre. This survey included questions that asked how they found out about the programme, their feelings towards the programme itself and how well they believed it followed their lessons. The second set of surveys was addressed to the Head of Science and faxed to 210 (about 94%) of England's science status schools and 35 (about 10%) secondary schools in the London area. These surveys asked questions that were aimed towards the teachers' awareness of the Education Centre, because these schools may or may not have visited the Tower of London on a school trip without visiting the Education Centre. We also asked if they had any suggestions for raising awareness of the programmes. We chose to send the survey to all of the science specialist schools (6% were unreachable) because our liaison advised us that these would be the most likely to devote time and resources for science related school trips. We also chose a sampling of London schools because their proximity to the Tower of London would also make them likely candidates to visit the site.

We decided that surveying was the optimal method for gathering this information because it is straightforward and brief. We asked basic questions to elicit brief responses. It was also possible to reach more teachers by faxing a survey rather than calling schools, asking to interrupt their busy schedules and asking the questions over the phone. This method does, however, introduce the problem of interpreting the teachers' responses to open-ended questions since a personal conversation would have allowed us to ask for some clarification.

We designed our surveys in a manner that we believed would make them easier to quantify. We also used format of the survey to limit the length of responses given. Where it was possible, teachers were asked to answer either yes or no or were given a multiple choice to elicit a standard range of responses. For open-ended questions, we provided a limited amount of space in which to respond, thus eliciting brief, to-the-point responses. This made the information easier to tabulate and limited the range of responses to include more pertinent information.

3.4 Reasons for not Attending Programmes

If teachers are aware of the programmes, their reasons for not taking advantage of them could be divided into two categories: factors controllable by the Royal Armouries Museum and factors not controllable by the museum. Factors that are controllable by the museum would be easier to deal with than factors belonging to the latter category. Controllable factors could be that they do not feel the material science programmes are worthwhile for a school trip, or that the programmes do not adequately address the curriculum. Uncontrollable factors could include lack of school funding, transportation and staffing issues or lack of interest in taking school trips, which are no fault of the Royal Armouries Museum. Some factors also fall into a grey area. For instance, the Royal Armouries cannot control how much funding a school allots for school trips, but it may be able to provide a price break in order accommodate the school.

Follow-up questions on the general survey were used to ask why teachers do not visit if they are aware of the programmes. We provided limited space with which to respond to this question so that short, simple answers would be given and would thus make the responses easier to compare and quantify.

3.5 Web-based Teaching Aid

If we expect teachers to use our interactive teaching aid, we have to ensure that is actually helpful. To consider this aspect of our final product we sought direct input from teachers through our surveys. Our interviews with Higgins Armory staff also proved useful in answering this question. Also, as mentioned in the Background section, an investigation of other interactive aids helped to provide useful information on the structure and content of web-based learning tools. This research provided basic ideas on how to build the teaching aid tool, populate it with relevant content and possible ways maintain it in the future.

Our survey to previous visitors of the Education Centre asked what the Royal Armouries could do to better inform teachers about the programmes offered there. The general survey sent to London area and science specialist schools asked what specific topics they cover in their lessons as well as what topics would be important to include in a web-based teaching aid. It also asked whether or not such a web-based aid would encourage them to take advantage of the material science programmes at the Tower of London, and the reasoning behind their response.

3.6 Appealing to Students

The teaching aid is delivered as an online resource, available to anyone who has access to the internet. Designing an interactive, attention-grabbing educational website that contains enough information to be useful but not so much that it loses the interest of the user presents an interesting challenge. Since the principle objective of this web-based tool is for secondary school teachers to captivate the attention of their students, we knew that we had to include pictures, demonstrations and interactive portions rather than just bare-bones text. One of our original research goals was to learn what student find interesting in an educational aid.

Our original intention was to gather information about students' interests through a survey. With the help of teachers, we wanted children to spend a few minutes in the classroom to fill out an online survey containing several multiple choice questions about what would make an interactive educational website interesting and what types of things would make them lose interest. Several factors caused us to discard this objective shortly after arriving at our project site in London. One of the main factors was the limited time frame we were given to complete our project. With so many students in England, or the city of London for that matter, gathering and analyzing a representative sample would be too time-consuming given the timeline of our stay in London. We did not want to introduce too many aspects to our data collecting methods, deciding that more thorough consideration of a few methods would be better than a limited evaluation of many.

We were also advised by our project liaison, who recently left the teaching profession to become the Royal Armouries' Science Education Officer at Tower of London, that we would encounter many difficulties in such an endeavour. We were told that teacher's have a hectic schedule during the day and would find it difficult to take time out for such a survey. The availability of the internet in classrooms and making students or teachers aware of the survey in the first place would also present difficulties. All things aside, our liaison also informed us that student privacy regulations would interfere with our data collection.

We decided that some extra research was our best option. Studies have been performed with the specific task of gauging the attitudes of children to interactive

material, such as the IQP for the Australian Bureau of Statistics. Further research saved us time and resources but allowed us to obtain information that helped us to create a web-based tool that should be more attractive to students.

4. Results and Analysis

The information gathered from our various research methods was used to create what we believe is an effective teaching aid that will entice secondary school teachers to take advantage of the material science programmes offered at the Royal Armouries Museum's Tower of London Education Centre.

Surveys received from teachers who have recently visited the Education Centre confirmed the quality of the educational programmes offered there and the satisfaction of teachers with how closely the material relates to their curriculum. They also provided information on the kinds of things that attract teachers to take school trips to the Education Centre and how teachers find out about the educational programmes.

Ideas from interviews with Higgins Armory personnel were used to enhance the effect of our web-based teaching aid. Other web-based teaching aids with similar purposes to our intended product were also consulted in order to see examples of how content is organized and presented.

Surveys sent to the science specialist and London area schools who have not recently visited the Education Centre showed that the main reason for not attending is lack of awareness. A portion of the surveys also cited distance from the Tower of London as the reason for not visiting. This response was expected from the more distant schools and we realize that it is not possible for all schools to make the long trip to London. The data confirmed our initial assumption that the reason for low numbers in attendance of the material science programmes is lack of awareness, not any fault in the quality of the educational programmes.

From review of the United Kingdom's national curriculum and research of the Royal Armouries' collections at the Tower of London we were able to relate the two in what we believed to be an acceptable manner. By observing demonstrations and familiarising ourselves with the programmes taught at the Education Centre we were able to incorporate the very same material students would be learning into the content of our web tool. Further input from survey responses provided ideas for additional content and different ways of presenting content to make it more appealing to students.

4.1 Surveys and Interviews

Our web-based tool was constructed in what we believed to be an informative, yet appealing format for secondary school students. Pictures and interactive animations were incorporated, as well as the suggestions for appealing to students given by teachers in the surveys. Through our liaison Ms. Martin-Smith's acquaintances in the teaching profession, we were able to set up a field test for a nearly completed version of the web page. Input from the teacher and student surveys were used to make final revisions to our project.

Surveys of teachers show what we believe to be evidence that the problem faced by the Royal Armouries Museum is not a matter of offering mediocre educational programmes. Responses were received from 7 (18.4%) of the 38 secondary school teachers who have recently brought their students to the Education Centre. Given the options of 'very closely,' 'closely,' 'somewhat closely,' and 'not closely at all,' teachers were asked to select which one describes how well the material in the programme related to their curriculum. As seen in Figure 1, all but one teacher reported that they were related closely or very closely. This is indicative that the Education Centre has done a good job of tailoring their programmes to meet the classroom needs of teachers. Furthermore, as seen in Figure 2, all of the teachers claimed to be "very satisfied" with their students' experience at the Education Centre. When asked for the reasoning behind their level of satisfaction, teachers cited "positive feedback" from the children and that the hands-on aspects of the programmes heightened the experience.

Teachers gave multiple responses when asked what factors made them decide to take advantage of the educational programmes. Figure 3 shows that most of the teachers were attracted by the programmes' relation to the curriculum, while past experience with the Education Centre was also a major factor. This helps to further reinforce the high quality of the programmes. The previous visitors reported becoming aware of the programmes from past visits, phoning the Education Centre and from the Educational Centre's brochure. This indicates that the Royal Armouries' web is not a major tool for making teachers aware of the programmes. Our website is designed to change this.

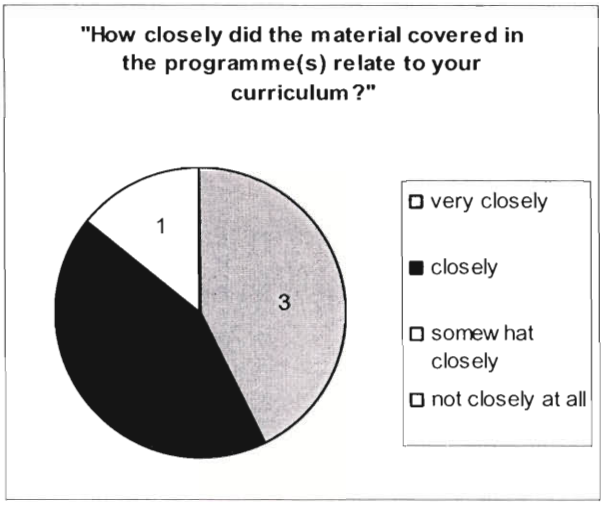


Figure 1: Graph showing the distribution of teachers' responses to the question "How closely did the material covered in the programme(s) relate to your curriculum?" These responses were given by teachers who have recently brought their students the Education Centre.

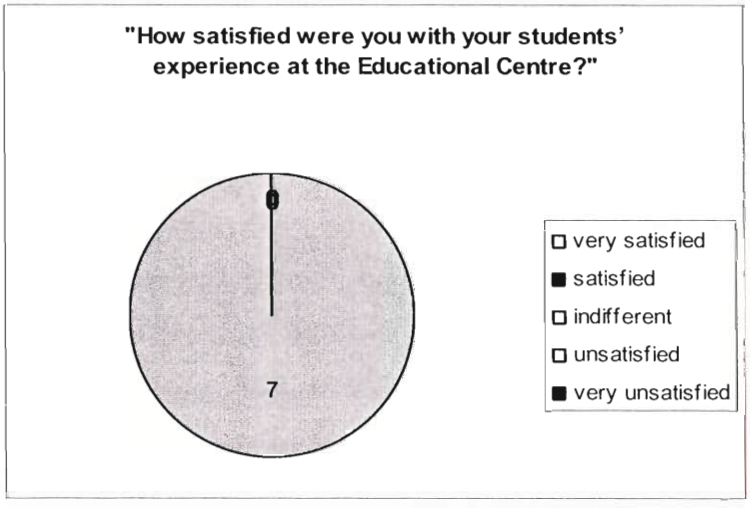


Figure 2: Graph showing the distribution of teachers' responses to the question "How satisfied were you with your students' experience at the Education Centre?" These responses were given by teachers who have recently brought their students the Education Centre.

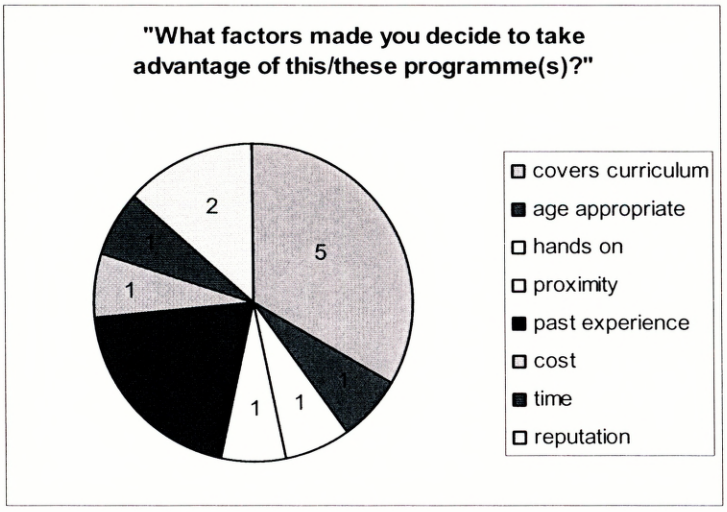


Figure 3: Graph showing the distribution of teachers' responses to the question "What factors made you decide to take advantage of this/these programme(s)?" These responses were given by teachers who have recently brought their students the Education Centre.

The shortcoming of this survey lies in the number of responses received. One may question whether failure to respond suggests dissatisfaction from the teacher. We hoped to entice more teachers to respond by offering entry into a draw for a free session. Another concern is that the respondents all attended history programmes, so the questions shed no light on satisfaction and relation to curriculum in regards to the science programmes. This was expected since the nature of the overall problem is the lack of schools attending the science programmes. We are confident, however, that the same level of satisfaction and adherence to curriculum would carry throughout all of the Royal Armouries' programmes.

While the survey of previous visitors shed light on why teachers choose to visit the Education Centre and why they approve of the programmes, our survey of heads of science at science specialist schools demonstrated why teachers do not visit the Educational Centre and what would make them more likely to visit. Figure 4 shows that 12 of the 14 responding science specialist schools reported never having visited the Tower of London. Statistically, it is unlikely that this ratio would be as high had all science specialist schools responded to the survey. In this case, familiarity with the Education Centre may have made those who previously visited more likely to respond. In the same sample of teachers, only one responded that they were aware of the

Education Centre at the Tower of London, and none of the teachers admitted to knowing about the educational programmes offered there. These data can be seen in Figure 5 and Figure 6, respectively.

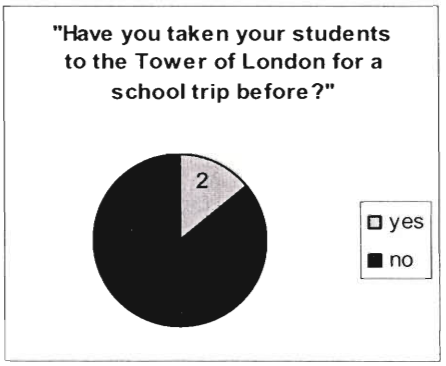


Figure 4: Graph showing the distribution of teachers' responses to the question "Have you taken your students to the Tower of London for a school trip before?" This survey was sent to 210 United Kingdom schools with the science specialist designation.

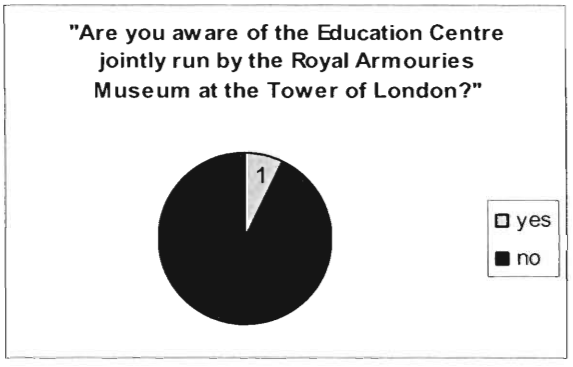


Figure 5: Graph showing the distribution of teachers' responses to the question "Are you aware of the Educational Centre jointly run by the Royal Armouries Museum at the Tower of London?" This survey was sent to 210 United Kingdom schools with the science specialist designation.

The survey also asked the heads of science whether or not a web-based teaching aid would encourage them to bring their students to the Education Centre. The results of this question, although not promising at first glance, are very encouraging. As Figure 7 shows, half of the respondents replied that they would be encouraged to visit by a web-based teaching aid, with three reporting that it would not encourage them.

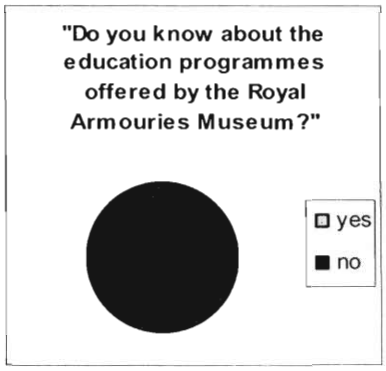


Figure 6: Graph showing the distribution of teachers' responses to the question "Do you know about the education programmes offered by the Royal Armouries Museum?" This survey was sent to 210 United Kingdom schools with the science specialist designation.

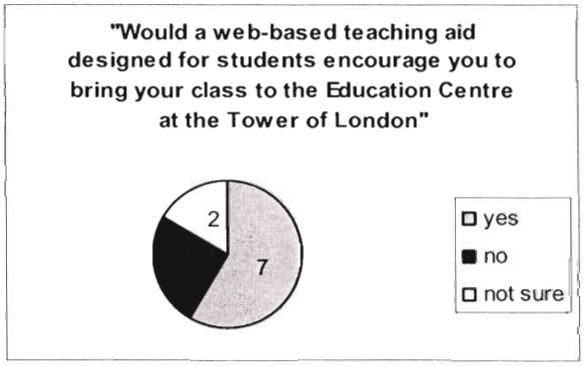


Figure 7: Graph showing the distribution of teachers' responses to the question "Would a web-based teaching aid designed for students encourage you to bring your class to the Education Centre at the Tower of London?" This survey was sent to 210 United Kingdom schools with the science specialist designation.

The follow-up to this question asked teachers to explain their reasoning. All three negative responses were explained by saying that they could not afford the time and/or money costs associated with a trip to the Tower of London because of the distance. As mentioned previously, we were aware that we would receive such responses since the survey was sent to schools all over the United Kingdom. However, despite being unable to visit the Education Centre, one teacher who replied "no" did say that they "would greatly appreciate being able to access up-to-date new materials/props etc. via 'electronic' means." This opened our eyes to a new aspect of our teaching aid: providing a way for schools who cannot visit the site to still experience some of what the Education Centre has to offer.

The teachers who answered that a teaching aid would encourage them to visit gave a variety of reasons. One teacher was encouraged by the ability to "access materials on the net to stimulate interest in the used material before making a visit." Another teacher stated it would be helpful if "work can be done prior to the visit to aid motivation and make a visit more useful with objectives clear before boarding a coach [bus]." Other teachers would find a teaching aid helpful because it would save them preparation time and "provide important follow-up back at school," as well as "justify time and cost." All of the responses from teachers mirrored our original intentions for the purpose of this web-based teaching aid.

In our interview with David Nangle, he reported that the Higgins Armory obtains information about Massachusetts standardized testing, primarily for the 4^{th} and 8^{th} grades, and tailors their exhibits and tours to what is tested. Mailings from the Armory advertise to teachers that their tours teach the material in order to attract them for school trips. Using this same strategy, our investigation of the United Kingdom's national science curriculum gave us an understanding of what teachers should be teaching their students about material science. The broad topics include classifying materials, changing materials and patterns of behaviour. The list of material science topics given by teachers in surveys reinforced those given in the national curriculum. Since the Education Centre has tailored its programmes to the curriculum, content for the web-based teaching aid could be taken directly from the programmes in order to appeal to teachers.

Curriculum-based content aside, many factors were taken into consideration when creating our web-based teaching aid. We decided to create a website that both teachers and students (or anyone else for that matter) could access in order to reach a wider audience. Although no formal studies have been performed to prove it, Mr. Nangle believes that people being able to find the Higgins Armory webpage through online search engines has been instrumental to encouraging visits to their facility.

Mr. Nangle also referred to obtaining outside statistics for learning styles to make tours and exhibits age appropriate. While creating the website, Ms. Martin-Smith gave advice for using the appropriate level of understanding and language suitable for secondary school students. We do not want the content to be so advanced that students

do not know what they are learning, but if the content is too elementary the students would be likely lose interest very quickly.

Mr. Nangle believes that one way to keep the interest of the audience is to get them involved. Our website includes several interactive portions, such as demonstrations of chemical reactions, in order to visually relate the material. Questions are dispersed throughout the sections of the website to encourage students to think about what they have been learning.

Results from the survey of teachers at science specialist schools were also used to plan the website. When asked what topics would be important to include in website about material science, most teachers responded by again listing some of the same topics they teach in the classroom. Many teachers, however, also suggested that the content should have real-life relevance to make it easier for the students to relate to. We included many references to significant real-life scenarios, such as the properties of semiconductors that make them an integral part of the computer industry and relating distillation to the refinement of different fuels from crude oil, just to name a few.

4.2 The Website

The web-based teaching aid covers various aspects of material science and gives examples of how the science is evident in the collections of the Royal Armouries' Museum and the Tower of London. Based on research of the national curriculum and the collections at the Tower, we established which topics would be the most practical to include.

Beside a picture of the White Tower, the main page of the website has the heading "Material Science at the Tower of London", links to the Armour, Crown Jewels, Sir Walter Ralegh, Longbow, and Gunpowder sections and logos and links to the web-pages of the Royal Armouries Education Centre's sponsors. It has a link to the glossary of terms, which can also be accessed by clicking any of the highlighted keywords throughout the text of the entire website, as well as a "Test Yourself" link, which leads to a ten question quiz covering the material presented in the web tool. For teachers using this tool, there is a link to a page that highlights all of the subjects covered by the National Curriculum that are included in the web tool.

The first section, "Armour - Periodic Table", contains the following subtopics, listed beside a picture of a suit of armour: Periodic Table, Periodic Table Trends, Element Information, Atoms, Reactive Metals, Non-metals, Poor Metals, Transition Elements, and Inert Gases. By clicking any of the subtopics, the page scrolls down to the part that covers that topic.

The Periodic Table subsection contains an interactive periodic table of elements. When the mouse is moved over an element of interest in the field of arms and armour (hydrogen, carbon, oxygen, aluminium, chromium, iron, silver, gold and lead), that cell of the table will enlarge, indicating that it may be clicked to bring up a window containing more information about that material and how it is significant to the history of the Tower of London. The windows pertaining to oxygen and hydrogen contain links to a separate window on Kevlar, which discusses its uses and has pictures of its structure and a Kevlar suit. The silver window has a link to a picture of silver used in the decoration of armour. Further text also explains how the periodic table is organised. Following this paragraph there is a picture of Einstein and a question that makes the

student apply what they have just read. These "Einstein Questions" are used throughout the website in every section to engage the students and make them recall content from the website. The questions also contain links to the answers so the children can see if they are correct.

The Periodic Trends subsection briefly discusses how atomic radii increase or decrease along rows and columns of the table as well as how reactivity is effected by row and column. The Element Information subsection covers notation for the periodic table and includes a diagram of a representative cell that shows what information the periodic table contains. In the Atoms subsection, a diagram of typical atomic structure is shown to help define protons, neutrons, electrons and electron clouds. The Reactive Metals subsection explains what it means to be a reactive metal and provides a visual that shows where the reactive metal elements are on the periodic table.

The last four subtopics, Non-metals, Poor Metals, Transition Elements and Inert Gases, all describe their respective elements and each includes a picture of where the elements are found on the periodic table. The Non-metals section covers information about oxidation numbers and halogens; Poor Metals discusses their properties and uses; Transition Metals discusses the ability of these elements to have more than one oxidation state; Inert Gases discusses the stability of these elements and contains a picture of a neon sign, since neon is one of these elements. A "Back" button is provided at the bottom of this section, as well as at the end of the other main sections, to bring the user back to the main menu and continue their exploration.

The "Crown Jewels - Material Properties" section is divided into five subsections: Diamond, Sapphire, Gold, Ruby, and Emerald. The first Diamond page includes many pictures and diagrams that compliment the text. Structures and compounds are discussed, and the structures of salt, diamond, and graphite are shown. The "Next" button brings the user to the second page of the Diamond section. This page gives a detailed description of hardness and includes a textual and pictorial representation of the Moh's scale for relative hardness. This page also contains three "Einstein Questions". A link at the bottom of the page leads to the Sapphire section.

The Sapphire section includes a note to the user that the gem is a compound and not an element, so it can not be found on the periodic table. The first Sapphire page

discusses boiling point and includes an animation showing a boiling pot of water. A link from this page leads to the section on distillation, which is related to boiling points. Clicking the "Next" button from first Sapphire page brings the user to the second Sapphire page. Here is a discussion of the chemical formulae of compounds, such as that of sapphire. The "Gold" button at the bottom of the page navigates the user to the next section.

The Gold section discusses density. A definition of the property and the equation for determining density are given on the first page along with examples and pictures that aid the learning process. The "Next" button leads to the second page of the Gold section, which discusses the properties of malleability and ductility. Pictures of materials exhibiting each property are shown. The golden dinnerware of the Regalia is shown for malleability, and leg mail is used as an example for ductility. The "Ruby" button at the bottom the page leads to the next section.

In the Ruby section, there is another reminder to the user that ruby is a compound and cannot be found on the periodic table. The first page of this section discusses melting point as a unique property of each element and compound. The "Next" button leads to the second page, which discusses properties of metals and non metals and includes a picture to illustrate each: iron and sulphur. From this section, a link at the bottom of the page allows the user to continue on to the Emerald section.

Once again, in the Emerald section there is a reminder that the material is a compound and not an element. The first page discusses standard states. A link at the bottom of the first page leads to the second page of the section, which includes a discussion of appearance. These are physical properties which are used to help visually identify materials. There is a picture shown of a material and the user is asked to describe it using what they have read on the page. This is to help students apply what they have learned. The bottom of this page has a link that returns the user to the "Crown Jewels – Material Properties" main menu.

The third major section of the webpage is "Sir Walter Ralegh – Distillation". This section has five subsections with the following names: "What is Distillation?" "Example of Distillation," "Fractional Distillation," "Crude Oil," and "Sir Walter Ralegh." To the right of the subcategory links there is a description of the distillation

demonstration offered at the Education Centre along with contact information. This makes teachers aware of the programmes offered and tells them how to get in touch with the Education Centre to schedule a school trip. To the left is a picture of the distillation apparatus used in the sessions at the Education Centre.

The "What is Distillation?" subsection includes a brief definition of distillation. The "Example of Distillation" subsection gives a simple scenario in which a solution containing salt and water is boiled to separate the two compounds. The "Fractional Distillation" subsection gives a definition of the method and summarises how it is used to separate multiple solutions. An illustration of a distillation apparatus with labelled components is given so students can see a visual representation of how the process works. The "Crude Oil" subsection describes one common use of fractional distillation, the rendering of many petroleum products from crude oil. This description is accompanied by a drawing that shows the layers and the products which come out of the distillation column. The last subsection discusses the role of Sir Walter Ralegh, a prisoner at the Tower of London, in performing early distillation experiments to purify his drinking water. The link at the bottom of the page navigates the user back to the main menu.

From the main menu, the "Longbow - Tensile Strength" link leads to the next section. This section includes a picture of a longbow that is on display at the Tower of London and a description of the Education Centre's programme that demonstrates the tensile strength of a longbow and bowstring. Again, contact information is given so teachers know how they can schedule a school trip. Below the description of the programme is a picture of the Houndsfield tensile strength testing machine used in the programme. This is shown to make teachers aware that the Royal Armouries' is well equipped to teach tensile strength sessions. The five subsection headings listed at the top of the page are "Long Bow Example," "Hooke's Law," "Rubber Band Example," "Bow String Materials," and "Potential Energy."

The "Long Bow Example" subsection describes the characteristics of a longbow and arrows and how they were made. Graphical print-outs from the Houndsfield tensile strength testing machine are shown to demonstrate how the force applied to the bow is used to shoot an arrow. The "Hooke's Law" subsection gives a brief definition of the

law, while "Rubber Band Example" helps demonstrate one example of a material that obeys Hooke's Law. The "Bow String Materials" subsection discusses the differences between hemp, string, rubber band and Kevlar as they would pertain to stringing a longbow. Additional graphs from the tensile strength testing machine show why each material would be suitable or unsuitable for stringing a longbow. The "Potential Energy" subsection discusses potential and kinetic energy and how they relate to the forces used to shoot a longbow. A link at the bottom of the page brings the user back to the main menu.

The last section is "Gun Powder - Chemical Reactions." This section is comprised of six subsections: "Chemical Equations," "Types of Reactions," Conservation of Atoms," "Balancing Equations," "Equation Balancing Test," and "6 Types of Chemical Reactions." "Chemical Equations" teaches the user the basics of reactants, products and equation notation. There is also an aside about the English historical figure Guy Fawkes, who was accused of using gunpowder to blow up the Houses of Parliament in 1605. By clicking on the "Next" button at the bottom of this page, the lesson continues with "Types of Reactions."

The "Types of Reactions" subsection discusses exothermic and endothermic reactions. A picture of a cannon firing is shown as an example of an exothermic reaction, and an animation of an endothermic reaction demonstrates this process. The "Next" button at the bottom of this page will bring the user to "Conservation of Atoms."

The "Conservation of Atoms" subsection explains the law of conservation of atoms and gives two examples; one is a possible reaction and one is an impossible reaction. Along with equations, diagrams of the example reactions are given to help explain the principle. The "Next" button brings the user to the next subsection, "Balancing Equations."

"Balancing Equations" goes through a step-by-step process one could use to balance a chemical equation. Diagrams for each step provide a visual of the equations and descriptions listed. The "Next" button brings the user to the second page of the equation balancing lesson. This page gives another step-by-step example using a different equation. Like on the first page, each step provides the equation, a description and a diagram. The "Next" button at the bottom of this page brings the user to the "Equation Balancing Test" subsection.

The user may test his/her equation balancing ability by taking the test. Nine unbalanced equations are provided for the user to solve. At the bottom, the "Answers" button will bring the user to the page that shows the correctly balanced equations. The "Back" button brings the user to the "Gun Powder - Chemical Reactions" menu.

The last subsection is "6 Types of Chemical Reactions." This subsection has a list of links named after the six types of common reactions: synthesis, decomposition, single replacement, double replacement, combustion and acid/base. Each of these links leads to a page about that type of reaction. Each page includes the following: a definition of the type of reaction, a general equation for that reaction, a specific example of a real reaction of that type and an animated demonstration of the reaction taking place.

5. Conclusion and Recommendations

The purpose of this web-based tool is for secondary school teachers and students to access information on the web about the material science programmes offered by the Royal Armouries Museum in the Tower of London's Education Centre. By using the internet, the Royal Armouries Museum can supply specific information about its programmes to a large audience and therefore, theoretically, reach more people than it could with a standard mailing of leaflets alone. A larger volume of information can also be transmitted more economically over the internet than with conventional methods of paper mailings. This teaching aid can be used in classrooms to help teachers teach material science in an interactive way. It can be used to prepare students for a session or serve as a useful follow-up to a school trip at the Tower of London's Education Centre. The content provided in the teaching aid covers the subject of material science as described in the United Kingdom's curriculum and establishes links to the Royal Armouries Museums' collections and the history of the Tower of London.

The website was well-received by the Royal Armouries Museum. Upon formal presentation of the website to fellow WPI students, WPI faculty and members of the Royal Armouries organisation, Irene Davies, Operations Manager of the Tower's Education Centre, showed interest in making CD-ROM copies of the website to be sent to schools as part of the regular Education Centre promotional mailings.

The team has some recommendations for anyone who wishes to make improvements to our version of the web-based teaching aid. Due to the limited amount of time allotted for this project, the team was not able to address every concern brought to our attention through our research. The team believes that these recommendations will help the teaching aid become more widely used by secondary school teachers in their classroom and also improve the quality of learning for the students.

One recommendation is to include the web address where the teaching aid can be accessed (when it is put online) in the leaflets that are sent out by the Royal Armouries Museum. From our survey results, it was brought to our attention that many secondary school teachers feel that the best way to increase teachers' awareness about the Education

Centre and its programmes is to send out detailed leaflets about the programmes. In a section of the leaflet that summarises material science programmes for secondary schools, a link for the website may be added for teachers to visit and use in their classrooms.

Another recommendation is to add interactive games to the teaching tool. The team had originally planned to use several interactive games about diamonds that are a current exhibit in the White Tower. Unfortunately, the sponsor of these games, DeBeers, advised that these games were not meant to be used on a website and therefore the size of the programmes would make it impractical to include them in our web-based teaching aid. Even though the teaching aid contains many interactive components, such as animations and simple demonstrations, it would be a great improvement to include some games to test the students' knowledge of the content he/she has just learned. These games should follow the content of each section; so the students could apply what he/she has learned in order to successfully win the game. More interactive demonstrations could also enrich the content. Adding more multimedia elements, sound for example, to existing portions of the website is also recommended.

The final phase of our project was to test it in an actual classroom setting. Andy Scott, a science teacher at St. George's Middle School, was gracious enough to allow us to test our web-tool in his classroom. We gave him a CD-ROM copy of the website in advance, which he uploaded to his school's network, allowing all of his students to access the page from the school's computer lab. He allowed the 31 students to use the web-tool unguided for two class periods, after which they were asked to fill out the surveys we made for him. We also asked Mr. Scott himself to evaluate the web-page from his perspective as a teacher. These surveys can be found in Appendix D and the results are shown in Appendix E. All of the students found the web tool easy to use, and most found the content useful, interesting and easy to understand. Mr. Scott informed us that he and the students found the website very easy to navigate, but some students needed help understanding the information. This suggests that the tool would be optimal when used with a teacher to guide the students. Mr. Scott said the tool was very helpful and that he is definitely planning to visit the Education Centre for a school trip. He also reported that the material was slightly too advanced for his year 7 class. Further work on the website

could aim to make the lessons a little simpler. Mr. Scott suggested that making each section shorter would allow the students to retain more of the information.

Mr. Scott and the students provided comments at the end of their surveys. Mr. Scott also asked his students to write a two-page review of their impressions of the website. Due to the time frame of the project, the web-tool trial was carried out on our second-to-last day in England, after the website was completed. Due to time constraints we did not have enough time to analyse this large amount of input. Our final recommendation is that these comments and reviews be evaluated to gain an in-depth understanding of how useful the students and instructor found the web-tool. The original surveys with comments and the printed reviews were left with our liaison, Mandy Martin-Smith, at the Tower of London's Education Centre.

Bibliography

Acaster, D., Jones, G., & Jones, M., (1993). *Camridge Coordinated Science: Chemistry*. Cambridge: Cambridge University Press.

Ashdown, C. H. (1911). *British Castles.* London: Adam and Charles Black.

Bickerstaffe, P. (1999). *The Heritage of the Longbow.* Great Britain: I.P. Bickerstaffe.

Billings, J., Hafner, A., Purtell, A., & Wilson, E. (2004). *"The Knight is Young" at the HM Tower of London.*

Bloomfield, T., Daniels, A., Dobson, K., Glover, A., Goode, T., Griffen, C., & Williams, G. (1991). *Co-Ordinated Science: GCSE Introductory Book.* London: Collics Educational.

Bloomfield, T., Dobson, K., Drury, J., Griffen, C., Irving, R., McCarty, C., Ratcliffe, M., Shewry, R., & Toone, A. (1992) *Co-Ordinated Science: GCSE Book 1.* London: Collins Educational.

Booth-Hewley, S., Edwards, J. E., Rosenfeld, P., & Thomas, M. D. (1997). *How to Conduct Organizational Surveys: A Step-By-Step Guide.* Thousand Oaks: Sage Productions.

Bowen, B. D., Krosnick, J. A., & Weisberg, H. F. (1996). *An Introduction to Survey, Research, Polling and Data Analysis.* Thousand Oaks: Sage Productions.

Bunker, B. B., Pearlson, H. B., & Schulz, J. W. (1975). *A Student's Guide to Conducting Social Science Research*. New York: Human Sciences Press.

D'Auvergne, E. B. *The English Castles*. London: T. Werner Laurie.

Department of Education and Skills. (2004). Retrieved November 16, 2004, from http://www.dfes.gov.uk/index.shtml

DiDonato, A., Leach K., & O'Bryant, M. (2003). *Her Majesty's Tower of London: Educational Materials for Children Under 5*.

Dillon, R. F., & Sternberg, R. J. (1986). *Cognition and Instruction*. San Diego: Academic Press, Inc.

Dufty, A. R. (1968). *European Armour in the Tower of London*. London: Her Majesty's Stationery Office.

Duschl, R. A. (1990). *Restructuring Science Education: The Importance of Theories and Their Development*. New York: Teachers College Press.

Farrell, M. (2001). *Key Issues for Secondary Schools*. London: Routledge Falmer.

Frey, J. H., & Oishi, S. M. (1995). *How to Conduct Interviews by Telephone and in Person*. Thousand Oaks: Sage Productions.

Gunja, N., Jaecksch, J., & Vauntin, J. (2003). *Web-Based Statistics Education for Schools*.

Hindley, G. (1968). *Great Buildings of the World: Castles of Europe*. Norwich: Fletcher & Son.

Historic Royal Palaces. (2004). Retrieved November 1, 2004, from http://www.hrp.org.uk.

Hogg, G. (1969). *Castles of England.* New York: Arco Publishing Company, Inc.

Horton, S. (2000). *Web Teaching Guide: A Practical approach to Creating Course Web Sites*. [Electronic Version]. New Haven: Yale University Press.

Jones, E. A. (2002). *Transforming the Curriculum: Preparing Students for a Changing World*. San Francisco: Jossey-Bass Inc.

Karcheski, W. J. Jr. (1995). *Arms and Armor in the Art Institute of Chicago.* Boston: Bulfinch Press.

Kemmis, S., & McTaggart, R. (1985). *The Action Research Planner*. Victoria: Deakin University.

Kitagawa-DeLeon, M., Lilas, Z., McBane, G., McDonald, N., & Singer, S. (2004) *Chemical Reactions*. Retrieved January 19, 2005, from http://www.ric.edu/ptiskus/Chem_Review/Index.htm

Lapper, I., & Parnell, G. (2000). *Landmarks in History: The Tower of London – A 2000-Year History.* Oxford: Osprey Publishing.

Loftie, W. J. (1886). *Authorised Guide to the Tower of London*. London: Harrison & Sons.

Made of Iron. (1966). Houston: University of St. Thomas Art Department.

Major Reform of Teen Schooling. (2004). [Electronic Version]. *BBC News*.

Mohs Scale of Mineral Hardess. (2004) Retrieved January 25, 2005, from http://en.wikipedia.org/wiki/mohs_hardness_scale

Norman, A. V. B., & Wilson, G. M. (1982). *Treasures of the Tower of London*. London: Lund Humphries Publishers Ltd.

Price, B. R. (2000). *Techniques of Medieval Armour Reproduction*. Colorado: Paladin Press.

Royal Armouries Museum. (2004). Retrieved November 1, 2004, from http://www.royalarmouries.org.uk

Stice, J. E. (Ed.). (1987). *Developing Critical Thinking and Problem-Solving Abilities*. San Francisco: Jossey-Bass Inc.

National Curriculum. Teaching Personnel. (2004). Retrieved November 17, 2004, from http://www.teachingpersonnel.com/go/teachers/overseas/teachingintheuk/curriculum/

Troy, S. (1955). *A History of Fortification From 3000 BC to AD 1700.* New York: The Macmillan Company.

Wragg, E. C. (2001). *Assessment and Learning in the Secondary School.* London: Routledge/Falmer.

Wragg, E. C. (2001). *Questioning in the Secondary School.* London: Routledge/Falmer.

UK School System. Y-Axis: Overseas Careers. (2004). Retrieved November 16, 2004, from http://www.y-axis.com/teachers/uk/schoolsystem.shtml

Appendix A: Profile of Sponsor

The Royal Armouries Museum is a government based organisation that was instated to preserve and display the United Kingdom's historical arms and armour. This organisation has three separate locations throughout the United Kingdom in Leeds, Fort Nelson in Portsmouth and at HM Tower of London. The Royal Armouries Museum's mission statement is "to promote in the UK and worldwide the knowledge and appreciation of arms and armour and of the Tower through the collections of the museum and the expertise of staff."

The Royal Armouries Museum does not manage the Tower of London site; that is done by another organization called Historic Royal Palaces. The Royal Armouries is a tenant at the Tower of London, and the collections are kept in the White Tower. The Education Centre is in the Waterloo Barracks building, near the White Tower.

Appendix B: Teacher Surveys and Cover Letters

Cover letter and survey sent to previous visitors of the Education Centre:

Dear ,

Our records have indicated that you have recently visited the Educational Centre jointly run by the Royal Armouries Museum at the Tower of London. We are contacting you to ask for help to create a better educational experience for your students at the Royal Armouries Museum during a future visit.

We are a group of four students from Worcester Polytechnic Institute in Massachusetts, USA, and we are in London completing a project for the Royal Armouries Museum at the Tower of London. It is very important that we obtain your input because there may be valuable programmes at the Education Centre that may be overlooked and underused by secondary schools.

We would greatly appreciate it if you helped us by completing this quick survey as soon as possible so that we can create a teaching aid for schools to use in conjunction with the curriculum that you teach in your classrooms. Every completed survey will be entered in a draw for a free workshop at the Tower of London. You can submit the completed survey via email (john_r@wpi.edu), fax (020 7481 2922), or post (we will provide a pre-stamped envelope upon request). After reviewing your answers, we may wish to contact you regarding the responses you have given to better assess your feelings towards the Education Centre. We thank you for your time and we hope to help you and your students find a better way to teach and learn science through history that is both educational and fun.

Yours faithfully,

Tiffany Gendall
Adrian Misiak
Jonathan Rogers
Matthew Young

Each submitted entry will be entered in a draw for a free workshop at the jointly run Royal Armouries Museum Educational Centre at the Tower of London.

Surveys can be submitted via:

Fax: 020 7481 2922
Email: john_r@wpi.edu
Post: Royal Armouries
H M Tower of London
London EC3N 4AB
(for a pre-stamped envelope, please dial the office at 020 7488 5658)

Name:

School:

Contact Information:

Best time to contact:

1. What educational programme(s) did your students attend at the Royal Armouries Museum's Educational Centre at the Tower of London?

2. How did you find out about this/these educational programme(s)?

3. What factors made you decide to take advantage of this/these programme(s)?

4. How closely did the material covered in the programme(s) relate to your curriculum?

   - ☐ Very Closely
   - ☐ Closely
   - ☐ Somewhat closely
   - ☐ Not closely at all

5. Please explain the reasoning for your response to question 4.

6. How satisfied were you with your students' experience at the Educational Centre?

   - ☐ Very Satisfied
   - ☐ Satisfied
   - ☐ Indifferent
   - ☐ Unsatisfied
   - ☐ Very Unsatisfied

7. Please explain the reasoning for your response to question 6.

8. What could the Educational Centre do to improve the quality of the programme?

9. What could the Educational Centre do to inform other secondary school teachers about the programmes offered at the Royal Armouries Museum?

You have completed the survey.
Thank you for your time and valuable input!

Cover letter and survey sent to science specialist and London Borough schools:

Attn: Head of Science

Dear Sir or Madam,

We are contacting you to ask for your help with the Education Centre jointly run by the Royal Armouries Museum at the Tower of London. We are polling local schools to obtain data that will help us to create a better educational experience for students at the Tower of London. Specifically, we are gauging educators' awareness of the science programmes offered at the Education Centre and how to make the programmes coincide with the school's curriculum. In return for your participation, you will be put in a draw for a free session for your students as a school visit to the Tower of London.

We are a group of four students from Worcester Polytechnic Institute in Massachusetts, USA, and we are in London completing a project for the Royal Armouries Museum at the Tower of London. It is very important that we obtain your input because there may be valuable programmes at the Education Centre that may be overlooked and underused by secondary schools.

We would greatly appreciate it if you helped us by completing this quick survey as soon as possible. By helping us, we can create a teaching aid for schools to use in conjunction with the curriculum that you teach in your classrooms. Every completed survey will be entered in a draw for a free workshop at the Tower of London. You can submit the completed survey via email (john_r@wpi.edu), fax (020 7481 2922), or post (we will provide a pre-stamped envelope upon request). After reviewing your answers, we may wish to contact you regarding the responses you have given to better assess your feelings towards the Education Centre. We thank you for your time and we hope to help you and your students find a better way to teach and learn science through history that is both educational and fun.

Yours faithfully,

Tiffany Gendall
Adrian Misiak
Jonathan Rogers
Matthew Young

Each submitted entry will be entered in a draw for a free workshop at the jointly run Royal Armouries Museum Educational Centre at the Tower of London.

Surveys can be submitted via:

Fax: 020 7481 2922
Email: john_r@wpi.edu
Post: Royal Armouries
H M Tower of London
London EC3N 4AB
(for a pre-stamped envelope, please dial the office at 020 7488 5658)

Name:

School:

Contact Information:

Best time to contact:

1. Have you taken your students to the Tower of London for a school trip before?

   ☐ Yes
   ☐ No

2. Are you aware of the Education Centre jointly run by the Royal Armouries Museum at the Tower of London?

   ☐ Yes
   ☐ No

3. Do you know about the science programmes offered by the Royal Armouries Museum?

   ☐ Yes
   ☐ No

   a. If you answered yes to the question above, have you taken advantage of these programmes with your students?

      ☐ Yes
      ☐ No

   b. If you do know about the science programmes offered but choose not to participate with your students, please list the reasons why:

4. Please list some topics related to material science that you teach your students, for example: metal and crystals properties, distillation, tensile strength, etc.

5. What educational topics would be important to include on a website designed to help teach students about material science?

6. Would a web-based teaching aid designed for students encourage you to bring your class to the Education Centre at the Tower of London?

   - ☐ Yes
   - ☐ No

7. Explain your reasoning for question 6.

8. What could the Educational Centre do to inform other secondary school teachers about the programmes offered at the Royal Armouries Museum?

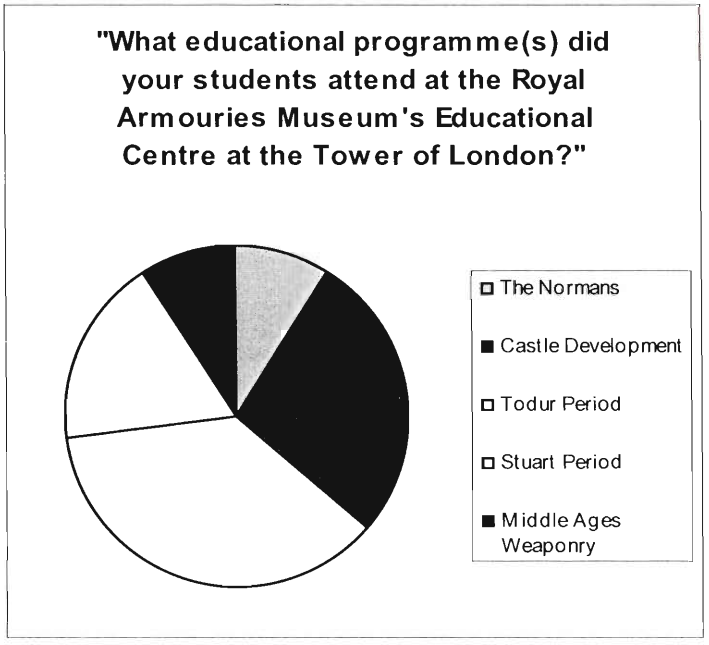
You have completed the survey. Thank you for your time and your valuable input!

Appendix C: Survey Data

Previous visitors' surveys:

What educational programme(s) did your students attend at the Royal Armouries Museum's Educational Centre at the Tower of London?

School	Responses
Friern Barnet	The Normans
Grey Coat	Castle Development
Iknield	Tudor period
Lynwen	Tudor and Stuart / Castle Development / Tudor Monarchy / Tudor Prisoners
Northcote Lodge	Castle Development
Southfields	Tudor Monarchy
Westgate	weaponry Middle Ages / Tudor and Stuart

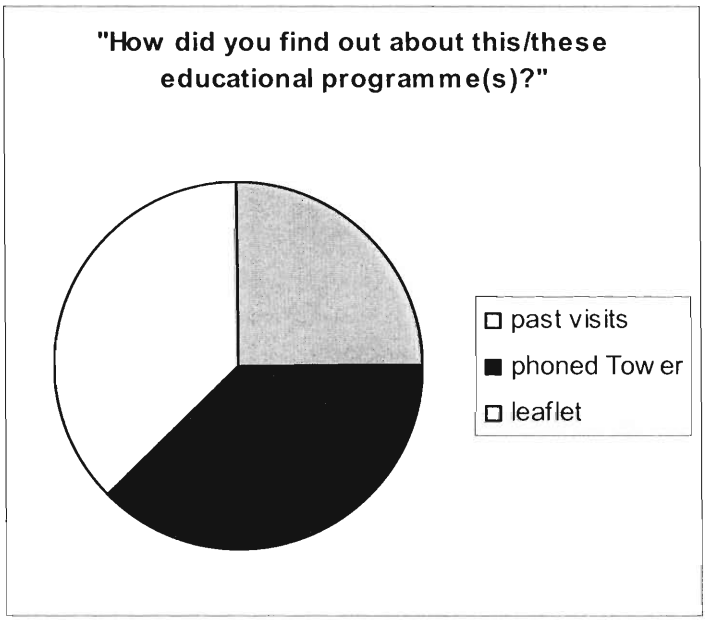


The Normans	1
Castle Development	3
Todur Period	4
Stuart Period	2
Middle Ages Weaponry	1

How did you find out about this/these educational programme(s)?

School	Responses
Friern Barnet	past visits
Grey Coat	leaflet / past visits
Iknield	phoned Tower
Lynwen	leaflet
Northcote Lodge	phoned Tower
Southfields	phoned Tower
Westgate	leaflet

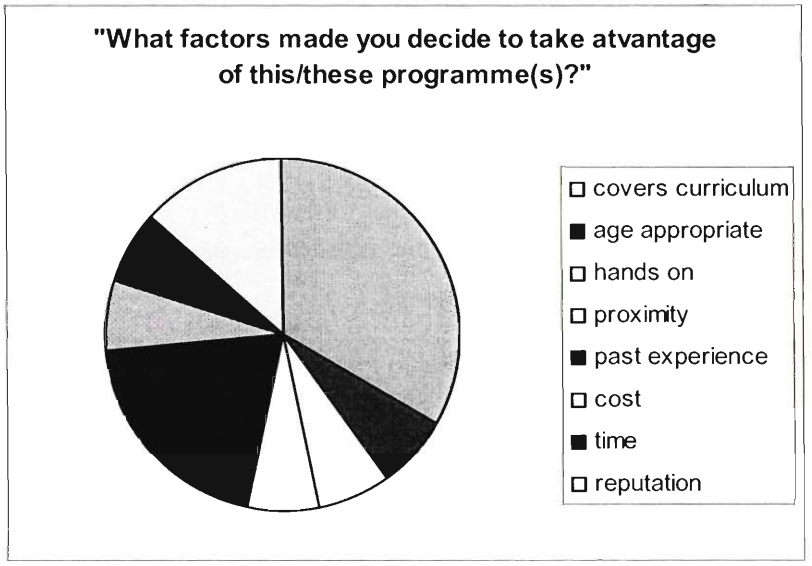
past visits	2
phoned Tower	3
leaflet	3



What factors made you decide to take advantage of this/these programme(s)?

School	Responses
Friern Barnet	curriculum related / Tower of London trip
Grey Coat	curriculum related / good past experience / cost factor
Iknield	hands on / significant period / good venue / informative personnel
Lynwen	learn and enjoy / been going for 20 yrs
Northcote Lodge	curriculum related
Southfields	appropriate for 12yrs
Westgate	reputation / avail times / proximity / curriculum

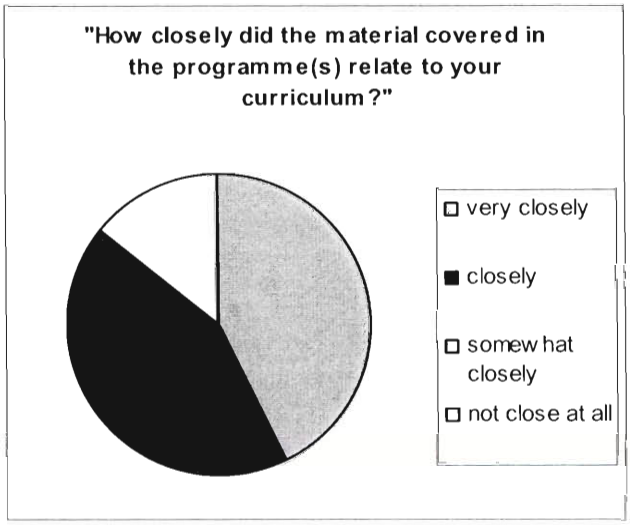
covers curriculum	5
age appropriate	1
hands on	1
proximity	1
past experience	3
cost	1
time	1
reputation	2



How closely did the material covered in the programme(s) relate to your curriculum?

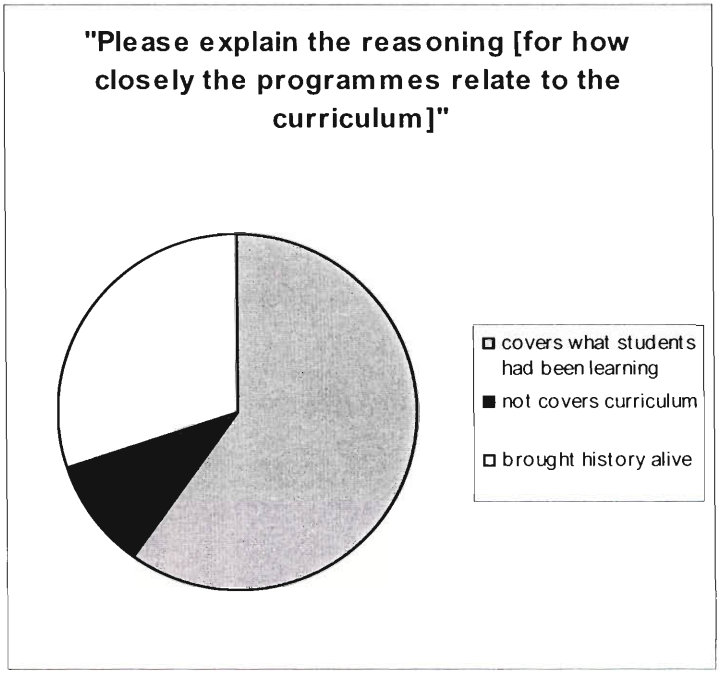
School	Responses
Friern Barnet	very closely
Grey Coat	closely
Iknield	somewhat closely
Lynwen	closely
Northcote Lodge	closely
Southfields	very closely
Westgate	very closely

very closely	3
closely	3
somewhat closely	1
not close at all	0



Please explain the reasoning for your response to question [above].

School	Responses
Friern Barnet	covers what students have learned
Grey Coat	covered what students have studied
Iknield	not cover curriculum due to linguistic/ cultural exchange
Lynwen	brought history alive / covered what students needed to know
Northcote Lodge	covered what students have studied
Southfields	brought history alive / covered what students needed to know
Westgate	brought history alive / covered what students needed to know

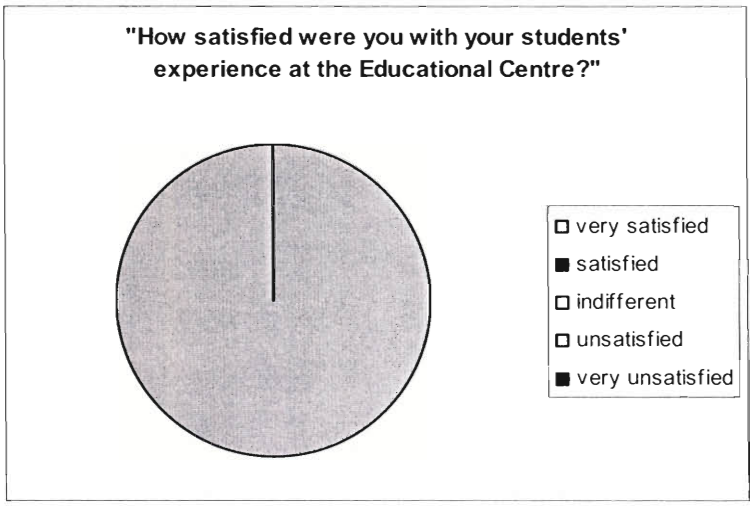


covers what students had been learning	6
not covers curriculum	1
brought history alive	3

How satisfied were you with your students' experience at the Educational Centre?

School	Responses
Friern Barnet	very satisfied
Grey Coat	very satisfied
Iknield	very satisfied
Lynwen	very satisfied
Northcote Lodge	very satisfied
Southfields	very satisfied
Westgate	very satisfied

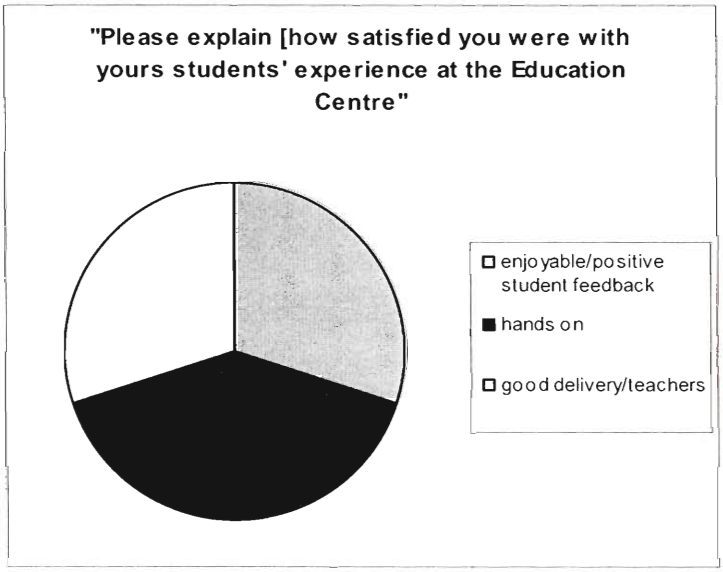
very satisfied	7
satisfied	0
indifferent	0
unsatisfied	0
very unsatisfied	0



Please explain the reasoning for your response to [the question above].

School	Responses
Friern Barnet	enjoyable / hands on replica
Grey Coat	good delivery / hands on
Iknield	positive feedback
Lynwen	good delivery
Northcote Lodge	a lot to see / do
Southfields	good teacher / costumes / good interaction
Westgate	learned / enjoyable

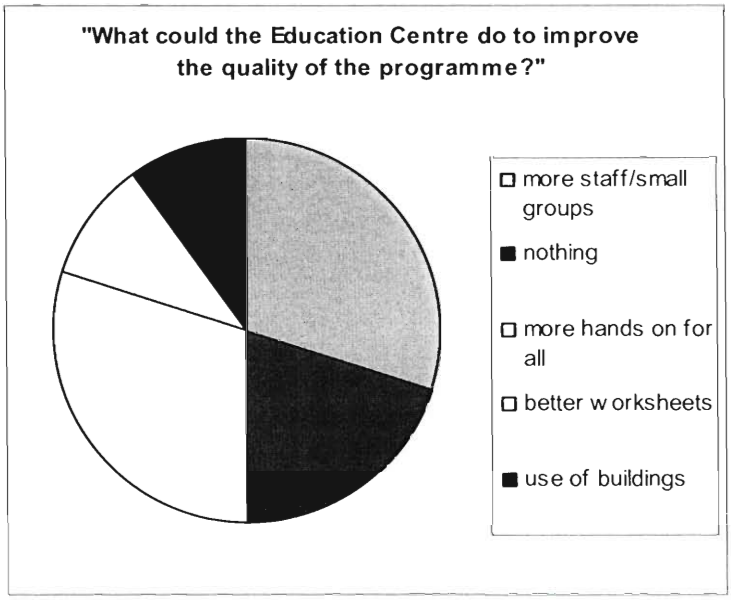
enjoyable / positive student feedback	3
hands on	4
good delivery / teachers	3



What could the Educational Centre do to improve the quality of the programme?

School	Responses
Friern Barnet	direct use of buildings / teach outside education centre
Grey Coat	nothing / more charismatic teachers / more hands on / better worksheets for KS3
Iknield	more staff for smaller groups
Lynwen	more hands on armour / more charismatic teachers
Northcote Lodge	nothing
Southfields	nothing
Westgate	all students try on

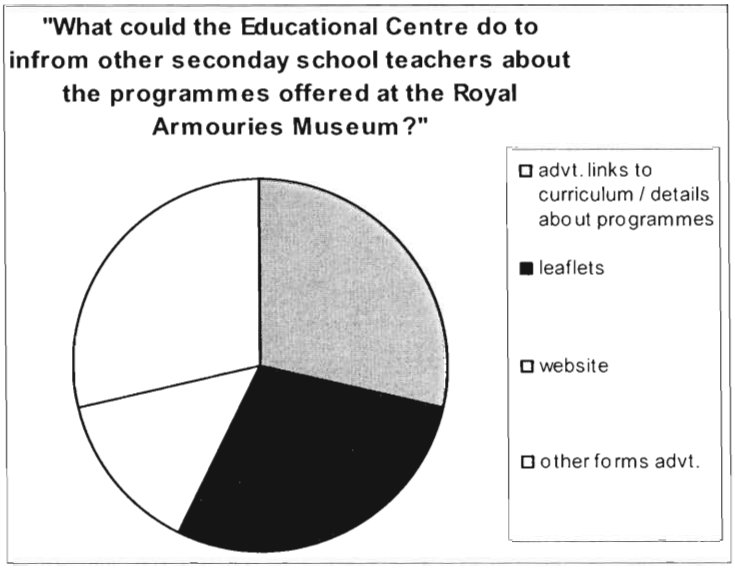
more staff/small groups	3
nothing	2
more hands on for all	3
better worksheets	1
use of buildings	1



What could the Educational Centre do to inform other secondary school teachers about the programmes offered at the Royal Armouries Museum?

School	Responses
Friern Barnet	advertise links to curriculum
Grey Coat	leaflets / use of website
Iknield	better forms of advertising to capture young and old
Lynwen	magazine
Northcote Lodge	send out leaflets
Southfields	email / fax info
Westgate	atten. to head of history / examples of all programmes

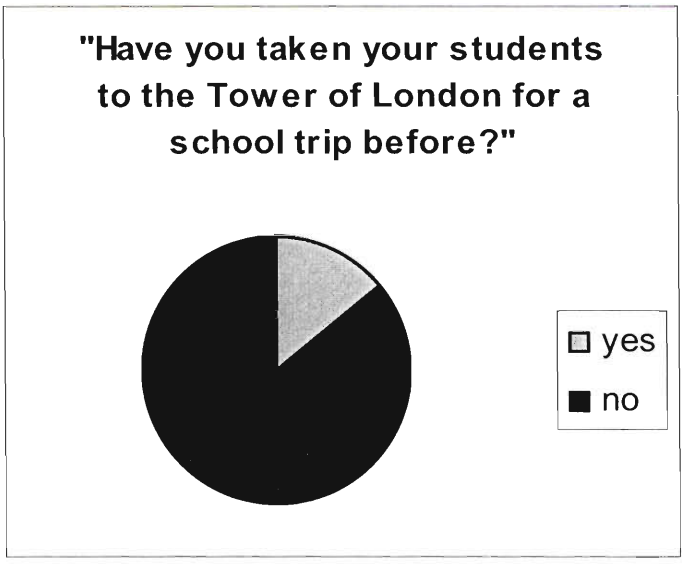
advertise links to curriculum / details about programmes	2
leaflets	2
website	1
other forms advertisement	2



Science specialist surveys:

Have you taken your students to the Tower of London for a school trip before?

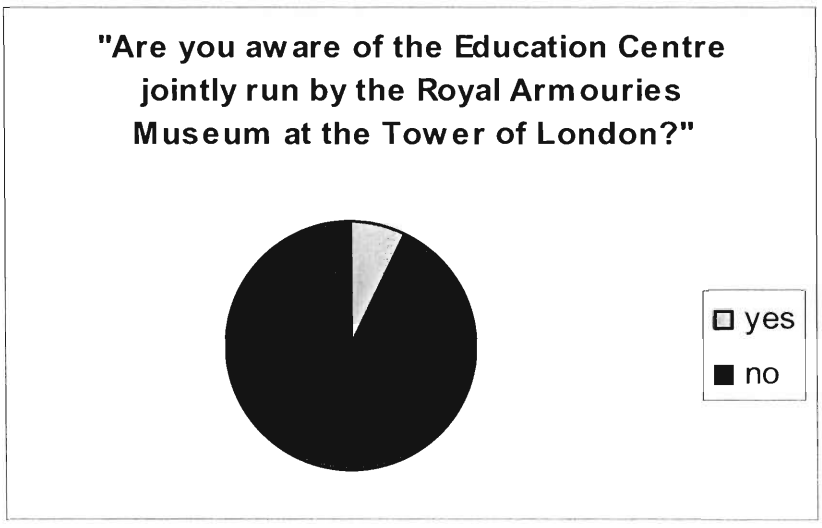
School	Responses
Bellerive	no
Carnforth	no
Court Moor	no
Hylands	yes
Monks Walk	no
Penair	no
Purbeck	no
St. Bernards	no
St. Cuthberts	no
St. Michals	yes
Sutton	no
Thurston	no
Urmston	no
Watford	no



yes	no
2	12

Are you aware of the Education Centre jointly run by the Royal Armouries Museum at the Tower of London?

School	Responses
Bellerive	no
Carnforth	no
Court Moor	no
Hylands	yes
Monks Walk	no
Penair	no
Purbeck	no
St. Bernards	no
St. Cuthberts	no
St. Michals	no
Sutton	no
Thurston	no
Urmston	no
Watford	no

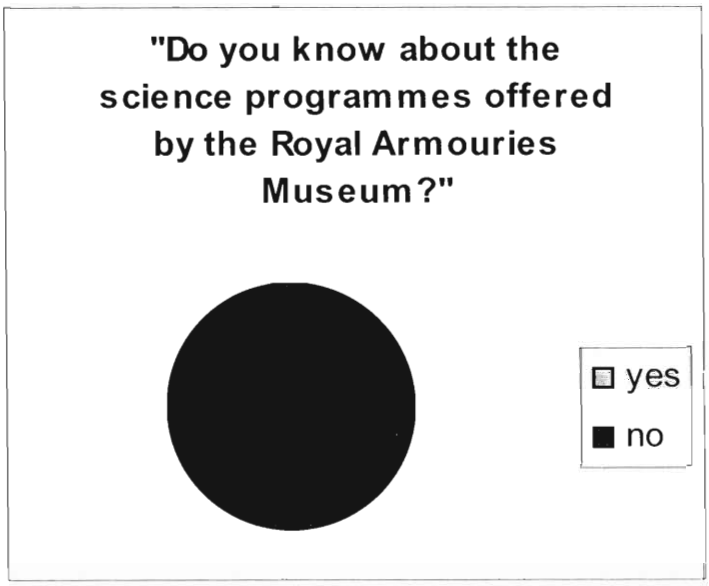


yes	no
1	13

Do you know about the science programmes offered by the Royal Armouries Museum?

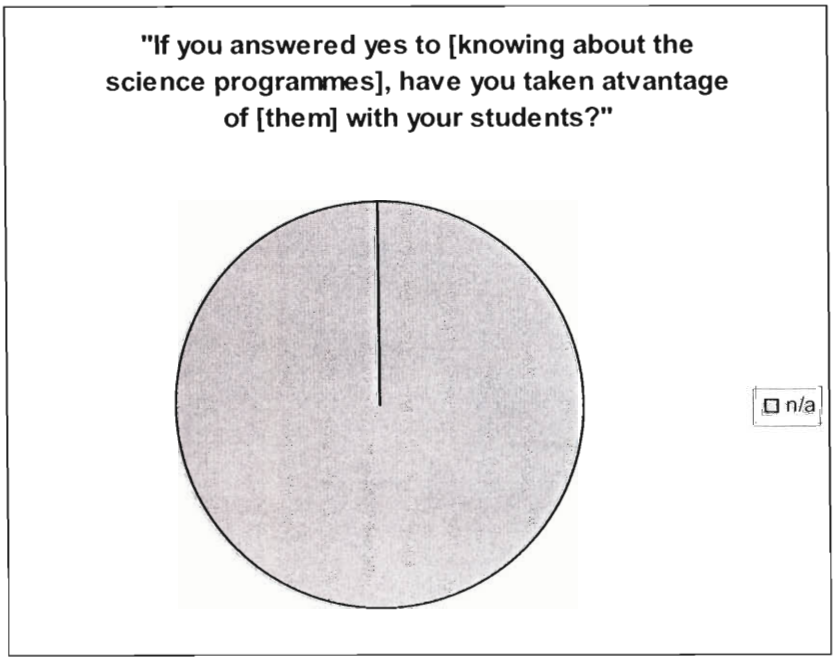
School	Responses
Bellerive	no
Carnforth	no
Court Moor	no
Hylands	no
Monks Walk	no
Penair	no
Purbeck	no
St. Bernards	no
St. Cuthberts	no
St. Michals	no
Sutton	no
Thurston	no
Urmston	no
Watford	no

yes	no
0	14



If you answered yes to the question above, have you taken advantage of these programmes with your students?

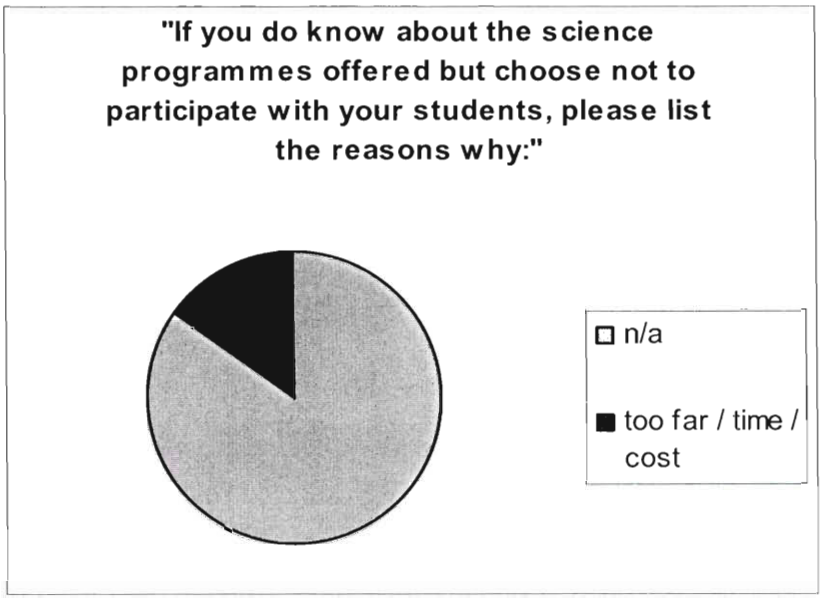
School	Responses
Bellerive	n/a
Carnforth	n/a
Court Moor	n/a
Hylands	n/a
Monks Walk	n/a
Penair	n/a
Purbeck	n/a
St. Bernards	n/a
St. Cuthberts	n/a
St. Michals	n/a
Sutton	n/a
Thurston	n/a
Urmston	n/a
Watford	n/a



If you do know about the science programmes offered but choose not to participate with your students, please list the reasons why:

School	Results
Bellerive	n/a
Carnforth	n/a
Court Moor	n/a
Hylands	n/a
Monks Walk	n/a
Penair	n/a
Purbeck	cost / transportation / time
St. Bernards	too far / time / cost
St. Cuthberts	n/a
St. Michals	n/a
Sutton	n/a
Thurston	n/a
Urmston	n/a
Watford	n/a

n/a	11
too far / time / cost	2

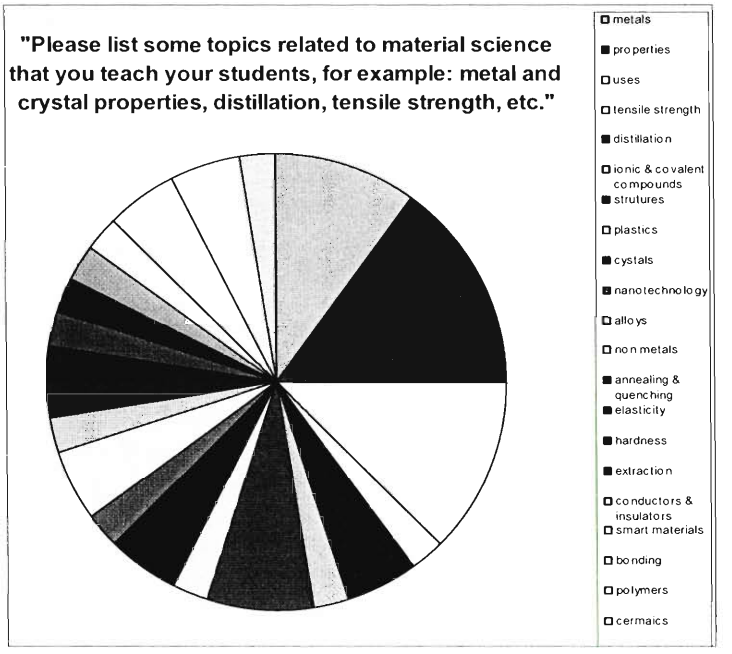


Please list some topics related to material science that you teach your students, for example: metal and crystals properties, distillation, tensile strength, etc.

School	Results
Bellerive	n/a
Carnforth	QCA
Court Moor	metals / properties and uses / alloys / rusting / structure / annealing / quenching / conductors / insulators
Hylands	elasticity / hardness / conductivity
Monks Walk	metals / polymers / ceramics / composites / properties and uses
Penair	metals / KS3 & 4
Purbeck	structure / bonding / properties / polymers / extraction / uses
St. Bernards	metals / properties and uses / alloys / distillation / non metals / extraction / crystalline structures
St. Cuthberts	n/a
St. Michals	plastics / nanotechnology / smart materials / hydro carbons
Sutton	materials / properties and uses / metals / structures / bonding / ionic and covalent compounds
Thurston	curriculum
Urmston	metal / crystals / properties / distillation / tensile strength
Watford	n/a

metals	4
properties	6
uses	5
tensile strength	1
distillation	2
ionic & covalent compounds	1
strutures	3
plastics	1
cystals	2
nanotechnology	1
alloys	2
non metals	1
annealing & quenching	1
elasticity	1
hardness	1
extraction	1
conductors & insulators	1
smart materials	1

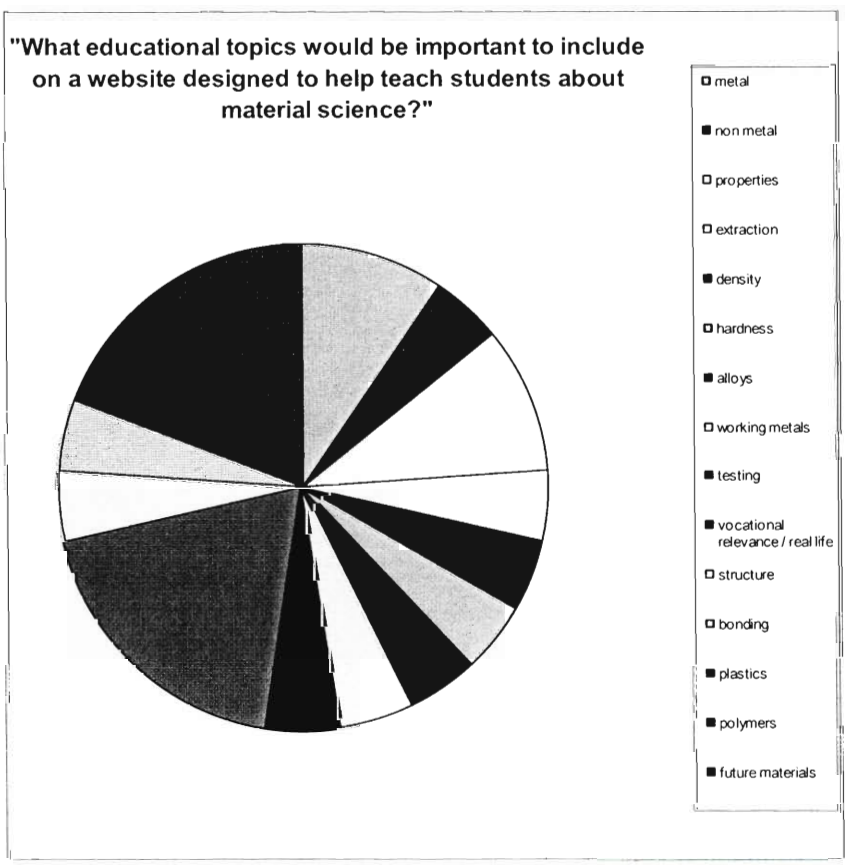
bonding	2
polymers	2
ceramics	1



What educational topics would be important to include on a website designed to help teach students about material science?

School	Responses
Bellerive	n/a
Carnforth	metal / non metal / properties / extraction / density / hardness
Court Moor	metals database / alloy comp / properties / working metals to swords
Hylands	material properties / testing / manufacture
Monks Walk	vocationally relevant
Penair	application to everyday life
Purbeck	application to everyday life
St. Bernards	metallic structures / bonding / future materials
St. Cuthberts	n/a
St. Michals	nanotechnology / future materials / plastics
Sutton	structure and bonding
Thurston	real life / relevant examples
Urmston	N04
Watford	relate to syllabus

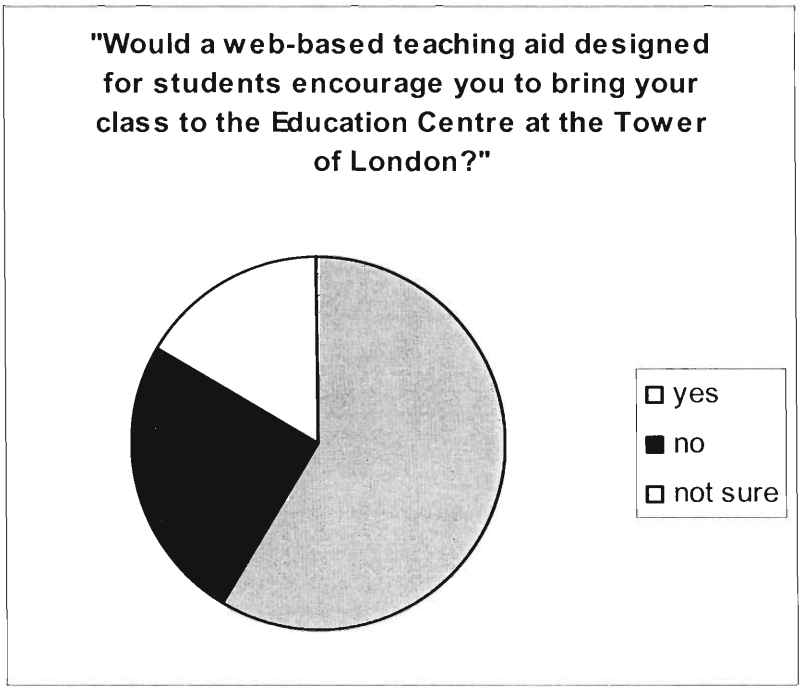
metal	2
non metal	1
properties	2
extraction	1
density	1
hardness	1
alloys	1
working metals	1
testing	1
vocational relevance / real life	4
structure	1
bonding	1
plastics	1
polymers	1
future materials	2



Would a web-based teaching aid designed for students encourage you to bring your class to the Education Centre at the Tower of London?

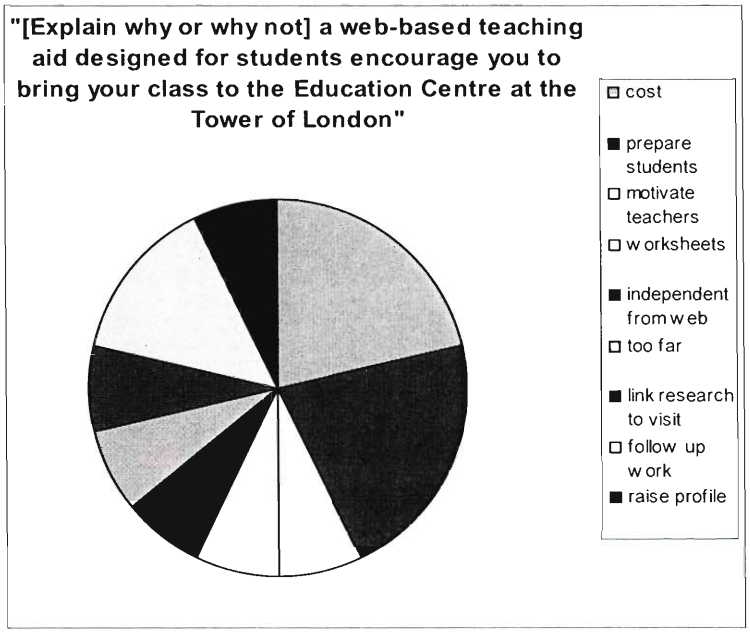
School	Responses
Bellerive	n/a
Carnforth	no
Court Moor	yes
Hylands	yes
Monks Walk	yes
Penair	?
Purbeck	yes
St. Bernards	no
St. Cuthberts	n/a
St. Michals	?
Sutton	yes
Thurston	yes
Urmston	no
Watford	yes

yes	no	not sure
7	3	2



Explain your reasoning for [the previous question].

School	Responses
Bellerive	n/a
Carnforth	costs
Court Moor	link research to visit / prepare students
Hylands	prepare students
Monks Walk	follow up work / raise profile
Penair	costs
Purbeck	justify time and cost / help teachers / follow up work
St. Bernards	too far
St. Cuthberts	n/a
St. Michals	n/a
Sutton	prepare students / motivate teachers
Thurston	CD-ROM to be independent from web
Urmston	costs
Watford	worksheets

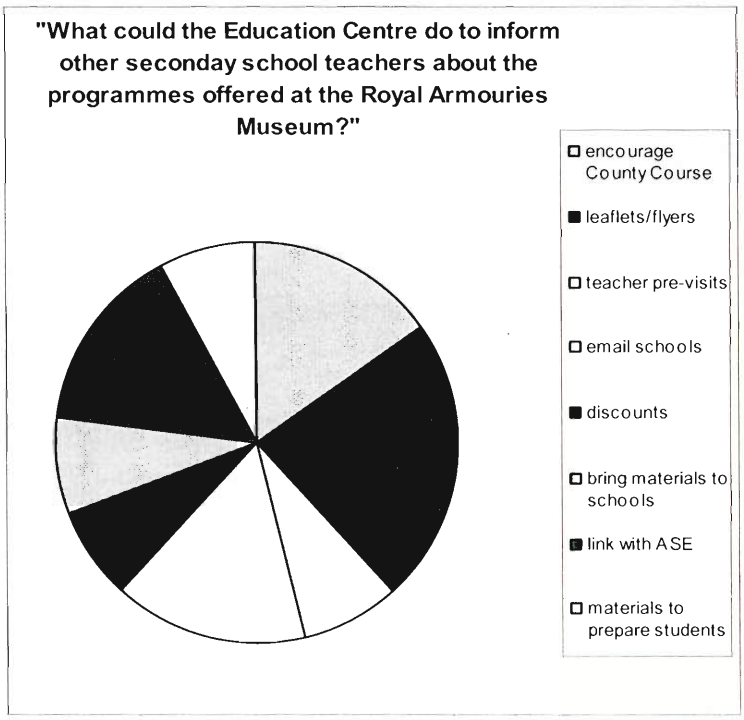


cost	3
prepare students	3
motivate teachers	1
worksheets	1
independent from web	1
too far	1
link research to visit	1
follow up work	2
raise profile	1

What could the Educational Centre do to inform other secondary school teachers about the programmes offered at the Royal Armouries Museum?

School	Responses
Bellerive	n/a
Carnforth	encourage County Course providers of INSET
Court Moor	leaflets / teacher pre-visits / material to prepare students
Hylands	Circulate info through Science Centres
Monks Walk	mail sheets / attend ASE events
Penair	link with ASE flyers
Purbeck	Science Centres
St. Bernards	email updates for schools too far away
St. Cuthberts	n/a
St. Michals	flyer / ASE Journal / teacher's magazine / TV channels
Sutton	email schools
Thurston	flyers / personal contact
Urmston	offer to bring materials to all schools
Watford	mail sheets / discounts

encourage County Course	2
leaflets/flyers	3
teacher pre-visits	1
email schools	2
discounts	1
bring materials to schools	1
link with ASE	2
materials to prepare students	1



Appendix D: Web-tool Trial Surveys

Student Survey:

1. Was this website easy to use?

   - ☐ Very Easy
   - ☐ Easy
   - ☐ Hard
   - ☐ Impossible

2. Did you find the information about material science on this website to be interesting?

   - ☐ Very interesting
   - ☐ Interesting
   - ☐ Boring
   - ☐ I fell asleep

3. Did you find the pictures and videos on the website helpful?

   - ☐ Very helpful
   - ☐ Helpful
   - ☐ Could be better
   - ☐ Useless

4. Was the content on the website easy to read and learn from?

   - ☐ I could understand all of the information easily
   - ☐ I could understand most of the information
   - ☐ I had a hard time understanding some of the information
   - ☐ I could not understand any of the information

5. Which things did you enjoy learning about most? (tick any that apply)

   - ☐ The Crown Jewels and structures
   - ☐ Arms and Armour and the periodic table
   - ☐ Gun Powder and chemical equations
   - ☐ Sir Walter Raleigh and distillation
   - ☐ Long Bows and tensile strength

6. Explain what your favourite and least favourite things are about this website.

_____

_____

Name and age (optional): _____

St. George's C of E Middle School

Quick Test

1. What part of an atom has a small negative charge?

    a. Electrons
    b. Neutrons
    c. Protons

2. The size of an element on the periodic table follows what trend?

    a. Right to left and top to bottom
    b. Bottom to top and right to left
    c. Left to right and bottom to top
    d. Top to bottom and left to right

3. What is the "hardest" mineral on Earth?

    a. Diamonds
    b. Rubies
    c. Sapphires
    d. Emeralds

4. The density of an object can be described by which equation?

    a. D=m X V
    b. D=W/V
    c. D=V/m
    d. D=m/V

5. Every balanced chemical equation has the same number of atoms on the left side of the arrow as it does on the right side of the arrow

    a. True
    b. False

6. What kind of reaction is the following : $2Zn + 2HCl \rightarrow 2ZnCl + H_2$

    a. Double Replacement
    b. Synthesis
    c. Single Replacement
    d. Acid/Base

7. Long bows are traditionally made out of what type of wood?

    a. Maple
    b. Yew
    c. Oak
    d. Pine

e. Teacher Survey

1. Did you find this aid easy to navigate?

   - ☐ Very easy
   - ☐ Somewhat easy
   - ☐ Difficult
   - ☐ Impossible

2. Did the students need help navigating the aid?

   - ☐ Most students needed help navigating the aid
   - ☐ Some students needed help navigating the aid
   - ☐ Very few students needed help navigating the aid
   - ☐ No students needed help navigating the aid

3. Did the students need help understanding (reading or learning) the information presented on the aid?

   - ☐ Most students needed help understanding the information
   - ☐ Some students needed help understanding the information
   - ☐ Very few students needed help understanding the information
   - ☐ No students needed help understanding the information

4. How closely did the material in the teaching aid relate to your curriculum?

   - ☐ Very closely
   - ☐ Closely
   - ☐ Somewhat closely
   - ☐ Not closely at all

5. Did you find this aid to be a helpful tool for teaching material science and history?

   - ☐ Very helpful
   - ☐ Helpful
   - ☐ Somewhat helpful
   - ☐ Not helpful at all

6. How has this teaching aid changed your interest in visiting the Education Centre at the Tower of London for a science-related school trip?

   - ☐ Definitely planning to visit
   - ☐ More willing to visit
   - ☐ Less willing to visit
   - ☐ Feelings not changed

   6a. Please explain the reasoning for your response

   _____

   _____

   _____

7. Did this aid keep your students' interests?

   - ☐ Yes
   - ☐ No
   - ☐ Somewhat

8. Did this aid help to teach your students material science in an interactive way?

   - ☐ Yes
   - ☐ No
   - ☐ Somewhat

9. How appropriate to the academic level of your students was this teaching aid?

   - ☐ Far to advanced
   - ☐ Too advanced
   - ☐ Appropriate to their level
   - ☐ Too basic

10. Overall, are you satisfied with the quality of this aid?

    - ☐ Very satisfied
    - ☐ Somewhat satisfied
    - ☐ Not satisfied at all
    - ☐ Would never use it

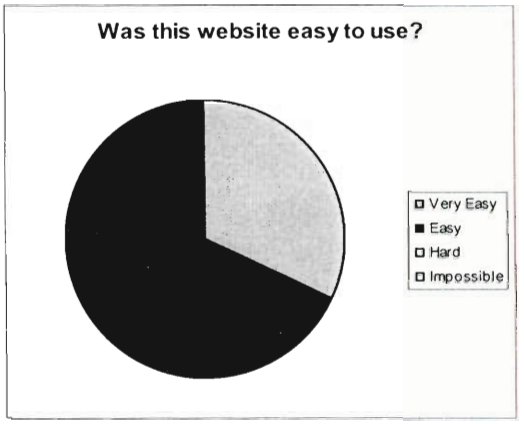
11. Was the level of interactivity appropriate for your students?

    - ☐ Very appropriate
    - ☐ Somewhat appropriate
    - ☐ Not appropriate at all

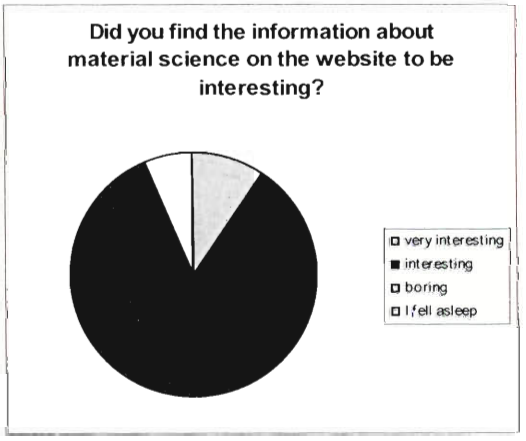
12. Please write down any comments or suggestions

Appendix E: Web-tool Trial Student Survey Results

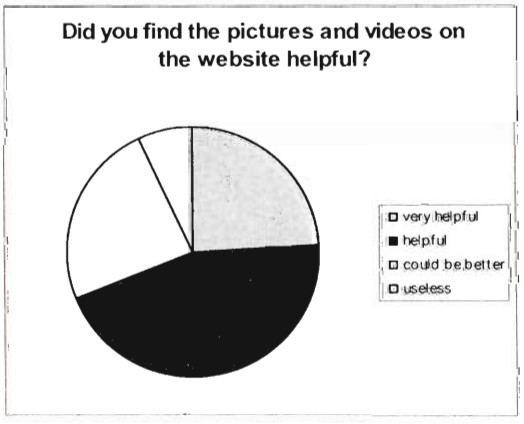
Very Easy	10
Easy	21
Hard	0
Impossible	0



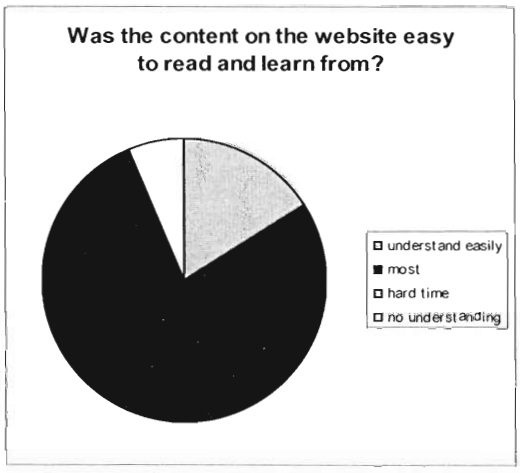
very interesting	3
interesting	26
boring	2
I fell asleep	0



very helpful	7
helpful	13
could be better	7
useless	2



understand easily	5
most	24
hard time	2
no understanding	0



Crown Jewels	12
Armour	16
Gun Powder	18
Sir Walter Ralegh	5
Low Bow	11