HM TOWER OF LONDON: SCIENCE OUTREACH LEARNING ZONE AT THE ROYAL ARMOURIES

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Abstract

This report, prepared for the Royal Armouries Material Science Learning Zone at HM Tower of London, details the design, creation, and evaluation of a loan box outreach program focusing on the material science of polymers. Hands-on learning activities have been shown to increase the amount of information students retained, thus the loan box will primarily contain this type of activities supplemented by literature and lecture materials. The project intends to spark interest in materials science in students at the Key Stage 3 level as part of an initiative to address a much larger issue; namely, a declining interest in the sciences in the UK.

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1. Introduction

Over the past several years, the UK has experienced a decline in the number of students pursuing degrees in science. If the decline continues, the UK will find itself dealing with a severe shortage of doctors, researchers, engineers, and others in the scientific professions. Within the past seven years, 30% of university physics departments have had to merge or close and there has been a 23% decrease in the number of universities offering Bachelor of Science in Chemistry degrees (Roper, 2006). A report by the House of Lords indicates that many students feel the physical sciences are no longer "fashionable" compared to newer courses of study such as psychology and photography (House of Lords, 2006), so fewer students are pursuing studies and careers in science. In addition, common complaints about science courses are that the syllabi are repetitive (Bury, 2005) and the facilities and teaching methods are lacking (Roper, 2006). The subjects are known to be difficult at the A-level, and they are increasingly being taught by non-specialized teachers. When these teachers show difficulty with the subjects, students will also perceive them as difficult and choose not to continue those studies (Bury, 2005).

Informal education is defined as education that "happens outside the classroom, in after-school programs, community-based organizations, museums, libraries, or at home" (*Enhancing education: Formal vs. informal education.* 2002). It is less structured and regulated than formal classroom education and, as such, is not standardized. Formal education, because it is government-regulated and highly structured, can be slow to change even if there is a clear need. In England only 35% of students reported relating what is being learned in science to their daily lives compared to an international average of 57% (Chrostowski, Gonzalez, Martin, and Mullis, 2003). In an effort to do their part to reverse this decline in interest in the sciences, many museums of science and technology are developing outreach programs and creating interactive exhibits with the hope of stimulating excitement about science and encouraging further study. In addition, the formal education system has been making a conscious effort to emphasize science and to encourage students to pursue science degrees. In May of 2007, the United Kingdom government announced a plan to promote interest in science in order to "meet the needs of the knowledge economy and underpin the country's science and engineering base" (Department for Children, Schools and Families, 2007).

Studies have shown that students often demonstrate greater interest and retain more material when they are taught by doing rather than the typical lecture-and-listen method of the classroom. The House of Lords, in a report on science and technology, states that "Practical work...is an absolutely essential component of effective science teaching" and cites a lack of practical learning opportunities as an underlying cause for students' lack of interest in science (House of Lords, 2006). A report by the Teaching and Learning Research Programme [TLRP] echoes this sentiment, saying, "Practical work is a distinctive feature of science education. External stakeholders often regard it as critical to improved student attitudes to science and to the uptake of more advanced science courses." (2006). Museum outreach programs are designed to provide students with engaging material and activities that fill this deficiency in practical learning experiences. While strong evidence is lacking, there is a belief among museum educators that providing students with positive and stimulating experiences in science early in their educational careers will encourage more students to pursue the study of scientific fields in higher education (Bruce, Bruce, Conrad, & Huang, 1996). The Royal Armouries at the Tower of London has designed their VisionWorks Material Science Learning Zone with these strategies and objectives in mind.

In order to reach those that are unable to travel to VisionWorks Material Science Learning Zone, the Royal Armouries wishes to create an outreach program in the form of a loan box containing hands-on activities and other interactive material to provide practical education in material science in the student's own school. The main objective of this project is to develop and test a loan box which will be sent to classrooms and serve as an extension of the Royal Armouries' VisionWorks Material Science Learning Zone. With the activities and interactive experiments included in the loan box, the Royal Armouries hope to stimulate interest in material science and encourage further study of the subject. Developing such a program will involve examining topics regarding the declining interest in science, material science as it relates to the National Curriculum, and the design and evaluation of successful outreach programs. This approach will entail background research, interviewing professionals with relevant experience, and the development of prototype program materials and activities. Prototype loan boxes will be tested at the Royal Armouries and feedback from students and teachers in the form of evaluations of the program elements and experiments will be obtained. The goal of the project is to create an effective loan box outreach program that stimulates interest in material science in parallel with the objectives of the Royal Armouries VisionWorks Material Science Learning Zone.

2. Literature Review

2.0 Background

Museums fulfill a wide variety of roles in modern society. First and foremost, they serve as centers of education and research, and many museums have education departments specifically geared toward supplementing the curriculum taught in schools. Often they have outreach programs which bring the museum to a class, rather than the class having to travel to the museum. These outreach programs come in a variety of formats, including guest lecturers, demonstrations or materials loaned out from the museum for a given period of time.

Before designing the loan box, it is important to first gain a complete and in-depth understanding of the various parts of the project including the history and importance of the Tower of London and Royal Armouries, the general mission and goals of museums, the evolution and importance of hands-on education and outreach programs and the curriculum in the UK for the target age group (i.e., Key Stage 3 (ages 11-14)). Each of these areas will be discussed in the following chapter.

2.1 History of the Tower of London & Royal Armouries

The Tower of London, built in 1078 as a fortress for William the Conqueror, is one of the oldest and best-known monuments in the United Kingdom. The original tower consisted of a single building: the White Tower. Over the past 930 years, it has grown to include many other towers and buildings, all of which comprise the castle known today as the Tower of London. The Tower of London's most notable historical role is that of a royal prison and execution site. Many notable figures in British history, including several wives of King Henry VIII, were beheaded on Tower Green. The Tower of London houses the Crown Jewels and many other historic artifacts and is one of London's biggest tourist attractions with more than 2.5 million visitors each year (http://europeforvisitors.com/ europe/countries/uk/tower-of-london.htm). The Tower is run by an organization called Historic Royal Palaces.

Though initially built as a treasury and residence for the King and his guards and household, over the years the Tower has also fulfilled the roles of menagerie, fortress, prison, armory and museum. In 1235, the Holy Roman Emperor gave Henry III three leopards as a gift. The coat of arms of the Plantagenet family, of which Henry III was a part, has three leopards (see Figure 1) to commemorate this event.

Figure 1: Plantagenet Coat of Arms (from http://www.renderplus.com/hartgen/images/plantagenet/parms.jpg)

Over the next twenty years, the menagerie grew to include a polar bear from the King of Norway and an elephant from France's King Louis IX. The public was allowed to come view the animals at the Tower (*London Encyclopedia,* 1986). There is also a much more grisly side to the history of the Tower of London. It is infamous for its role as a prison for royalty, nobles, and others. Two of King Henry VIII's wives, Anne Boleyn and Catherine Howard, were imprisoned there before their executions in 1536 and 1542, respectively. Other nobles imprisoned and/or executed at the Tower include Henry VI (1471), Sir Thomas More (1535), and Lady Jane Grey (1554) (French, 1986). Guy Fawkes and his co-conspirators were imprisoned there after their failed attempt to bomb Parliament in 1605. (history.uk.com). Even up through World War II, spies were imprisoned and executed within the Tower. Today, the Tower is no longer used as a royal residence but instead houses offices and museums (French, 1986).

As with any old building, the Tower requires constant maintenance of its physical structure. Because it has existed for so long and has seen so much history, special care must be taken to also preserve its historical and cultural heritage. The Tower has been listed as a World Heritage Site since 1988 and the organization that runs the Tower, Historic Royal Palaces, is also in charge of maintenance and upkeep of the Tower and its collections (*The Tower of London World Heritage Site Management Plan,* 2007). There are many restrictions on landscaping and development within the Tower grounds and also in the area surrounding the Tower. For example, Historic Royal Palaces must be notified if any development is going to occur within 800 meters of the Tower (p. 60). Similarly, building repairs are conducted using minimally invasive approaches that are intended to change as little as possible of the original structure of the Tower (p. 76). Historic Royal Palaces is also in charge of maintaining and preserving the Tower's collections, documents, and other artifacts. Perhaps the most important collection is the Crown Jewels, for which Historic Royal Palaces is in charge of the security, storage, care, and proper presentation (p. 75). Conservators are employed to repair and maintain the collections to ensure that they degrade as slowly as possible. They "combine scientific, preventative, and treatment skills and expertise" to protect the collections and help ensure their longevity (p. 77).

As it has been in the past, the Tower of London remains an icon of British (especially English) national identity and British royalty. Though it is no longer used as a royal residence, the Tower is home to several museums aiming to educate the public on British history. With over two million visitors a year, it remains "one of the capital's most prominent landmarks and a world-famous visitor attraction" (http://www.historic.uk.com). Somewhat surprising may be the fact that it is also the home of the Beefeaters, an elite group of guards who formerly guarded the gates and prisoners of the Tower and are now both ceremonial guards and tour guides (http://www.historic.uk.com). The Tower also houses several collections of armor and weaponry spanning the centuries of its existence. One of the largest and oldest collections is managed by the Royal Armouries.

The Royal Armouries has been housed in the White Tower since the Tower of London has been in existence and was opened to the public in 1660 when King Charles returned from exile (http://www.royalarmouries.org/extsite/view.jsp?sectionId=460). As such, it is the oldest museum in Britain and one of the oldest in the world. For the past four centuries it has specialized in the preservation and display of armor, weaponry, and torture instruments throughout history (http://www.britannica.com/eb/article-9105692/Royal-Armouries). Recently, the Royal Armouries has expanded to include locations in Leeds, Fareham, and Louisville, Kentucky.

2.2 History and Evolution of Museums

Any type of museum, be it an art, history, natural history or science museum or a zoo or aquarium, offers the visitor with sensations, ideas, and experiences not found in other places. The heart of every museum is its collections, which are used in many ways and shape a museum's identity. "Identity is essentially related to the type of museum and the material it exhibits" (Belcher, 1991). The identity of a modern museum shapes its mission. Many museums are designed to educate the visitor but also serve as research centers. They also serve to collect and conserve particular specimens and artifacts. Whatever the item, be it a panda at the Smithsonian National Zoological Park or an artifact at the Smithsonian National Museum of Natural History; it is protected by the museum for future use in education and research. "Museums are normally invested in missions that serve the public, and these missions are educational, aesthetic, scientific, or historical" (Kotler and Kotler, 1998).

Museums trace their history back to ancient Greece where they were scholarly religious, spiritual and creative centers. They were used by a very small number of select people and not the everyday person. The word *museum* actually comes from the Greek word *mouseion*, meaning 'a temple of the muses' (Kotler and Kotler, 1998), where in Greek mythology muses were goddesses of inspiration of the arts. In Rome during second century B.C., museums were used as storage areas and for the display of items won in military battles. The collections of military museums eventually sprouted other museums. In England, King Charles I was the first king who collected artifacts and works of art from other countries. He sent people all over the world in order to collect for him with the slogan, "Transplant Old Greece into England" (Kotler and Kotler, 1998).

"The tension in museums between serving scholars, connoisseurs, and savants on the one hand and encouraging public learning on the other grew in the eighteenth and nineteenth centuries" (Kotler and Kotler, 1998). Due to this competition, museums gradually evolved into broader, public-minded institutions. They continued to expand and differentiate into the museums that exist today. Museums evolved to appeal to a wider group of people and eventually opened to the general public. The first public museum, opened by Sir Ashton Lever in his Oxford home in 1774, contained artifacts that he had collected. This was the first museum that had been open to the general public, rather than being limited to select individuals. He charged an admission fee to cover the costs of the museum and to help regulate the number of visitors (Kotler and Kotler, 1998). The

British Museum soon followed suit on January 5, 1759, becoming a public museum when it opened to local residents with proper identification for one hour every day.

As the type of people who visited museums diversified, so did the design of museums. The design of early museums reflected the knowledge and understanding of their visitors, who were primarily educated, wealthy people. The typical nineteenth-century history museum displayed works of art and other artifacts with little to no information on the nature and history of the items on display (Kotler and Kotler, 1998). The target audience of educated people was expected to know enough about the objects on display such that extensive interpretation was unnecessary. This, however, severely limited accessibility to wider audiences. When museums became public, their design changed to appeal to a variety of visitors. Museums became educational tools to teach the general public about history and the nature of the world as opposed to collections of curiosities for the educated elite. This transition was seen throughout the late 18^{th} century and the 19^{th} century when public museums first arose and became increasingly popular. In recent decades, many museums have undergone fundamental changes in the ways in which they display and interpret items from their collections in order to engage broader audiences with various interests and learning styles. In an effort to remain vibrant and relevant, many museums have also developed extensive educational programs. Increasingly, modern museums are using interactive and multi-media presentations to enhance their exhibits and programs. “These interactive and multimedia museum presentations reflect recently developed educational concepts emphasizing multiple intelligences, diverse learning styles, and a range of culturally defined learning modalities” (Kotler and Kotler, 1998). Thirty years ago about one in ten Americans visited a museum at least once a year (Falk and Dierking, 2000). There was a steady rise in visitors up until the beginning of the 21^{st} century. Since then, the attendance at museums has reached a plateau. A study conducted by the American Association of Museums (AAM) in 2006 showed that museums receive over 600 million visits annually (http://www.aam-us.org/pressreleases.cfm?mode=list&id=116).

2.3 How Museums Educate

Museums are effective learning centers because of the fact that they provide informal learning, as opposed to schools which are formal resources for learning. “Informal settings such as museums offer untapped potential for communicating social, cultural and scientific information, correcting misconceptions and improving attitudes and cognitive skills.” (http://www.infed.org/archives/e-texts/screven-museums.htm) Education in a museum and other informal settings is led by curiosity, discovery and exploration as opposed to structured teaching. Visitors to a museum learn on their own during their visit, but museums also pay attention to the educational background of the visitors in order to effectively teach them. Museums are regarded as a very reliable source of information by Americans, even more so than books. Almost nine out of every ten Americans (87%) find museums to be trustworthy. No other institution has a level of reliability that high and 38% of Americans find museums to be one of the most trustworthy sources (http://www.manyonline.org/AmericansTrust.htm).

One strategy museums use to educate their visitors is to supplement the national or state curriculum in their exhibits. Jeffrey Forgeng, the curator of the Higgins Armory Museum in Worcester, MA (personal communication, November 9th, 2007), emphasized that the museum’s education department strives to connect the displays and outreach programs to the Massachusetts curriculum frameworks. The Higgins Armory Museum, along with many other museums, has outreach programs to supplement the museum experience or provide people with the museum experience if they cannot visit it themselves.

Museums often provide supplementary materials to continue to keep the visitor’s interest both during and after his or her visit. For example, the National Museum of Natural History offers a large introductory video in an IMAX theatre (Falk and Dierking, 2000). The video acts as a ‘hook’ or ‘entry point’ to grab the visitor’s attention. The museum also gives the visitor an accompanying brochure during the video to reinforce what they learned. These two methods are extremely effective for the museum because they grab the visitors’ attention visually through a modern technique and then reinforce its teachings through the reading of a brochure afterwards.

As noted, hands-on and interactive exhibits have become integral parts of the modern museum experience. “A hands-on or interactive museum exhibit has clear educational objectives which encourage individuals or groups of people working together to understand real objects or real phenomena through physical exploration which involves choice and initiative.” (Caulton and Tim, 1998) Consequently, the Royal Armouries at the Tower of London has developed the “Hands on History” exhibit that offer visitors the chance to, “wear a gauntlet, lift a musket, draw a bow and handle a sword as you explore the different roles of the Tower over the centuries and the important events of the last 1,000 years.” (http://www.hrp.org.uk/TowerOfLondon/WhatsOn/handsonhistory.aspx). Besides letting the visitors experience weaponry and armor, the exhibit includes large molds of coinage from Britain which serve as aids to teach the visitors about the time the Tower served as the Royal Mint.

The London Science Museum has several hands-on and interactive exhibits, including one which “tells you the sex of your brain.” The aim of these hands-on exhibits is to aid in the visitors’ understanding of a subject while still being engaging. A problem that has risen is the tendency for exhibits to focus more on being enjoyable rather than educating the visitor. Although these hands-on and interactive exhibits can be extremely informative while being entertaining, they cannot lose the original intention to educate the visitors.

> “It seems that both the development of science, and individual perception and understanding, require interactive experience with objects (including working models that can be constructed and handled) to approach and appreciate abstract theoretical principles...although hands-on experience is effective - indeed essential, for learning to see and understand - it can hardly be adequate for arriving at *scientific* understanding.” (Gregory, 2001)

Exhibition methods have evolved and now typically include high-tech materials and methods to engage the visitor. The Science Museum of London has interactive video games for visitors and a 3-D IMAX theater. The theatre is a primary example of how modern technology is incorporated to excite visitors. Much like hands-on exhibits, the use of modern technology and the teaching of science must keep the focus on the material being presented, not the elaborate technology. “Possibly though, as suggested by Michael Shortland (1987), we have been too free with phrases such as "Science is Fun", for much of science is tedious, difficult and sometimes dangerous.” (Gregory, 2001)

2.4 Exhibit Evaluation Research

In order to develop high quality exhibits and programs that walk this fine line between education and entertainment, museums conduct careful evaluations before, during, and after their implementation. Museums evaluate their exhibits in three forms of research: front-end, formative, and summative evaluation (Kotler and Kotler, 1998). Front-end evaluation is used in order to plan an exhibit or program. It usually involves asking visitors and educators their thoughts on exhibition or program concepts, goals and plans. This method of research gives the museum a greater sense of what teachers and typical museum-goers are looking for during their experience. Formative evaluation consists of surveying the public on museum prototypes, both in the museum and externally. The prototype research usually focuses on specific aspects of the exhibit or program, rather than the whole experience, in order to pinpoint problems and revise ideas. Finally, summative evaluation focuses on the finished exhibit or program, and usually involves surveys of exhibit visitors and program participants. This method is used in order to determine if the exhibit or program objectives were achieved and is occasionally used to look into modification of exhibit or program elements and features (Kotler and Kotler, 1998).

2.5 Teaching to Different Learning Styles

It has been recognized that people have different ‘learning preferences’, meaning that people learn and retain information more successfully depending on how they are taught. One example of this is the VARK program. The theory behind the VARK program is that each person has a preference in the way they absorb and give information: Visually, Aurally, Reading/writing, and Kinesthetically. The VARK program is a very simple sixteen-question questionnaire designed to inform the user of his or her preferred learning style (http://www.vark-learn.com/english/page.asp?p=faq).

Professor Chrysanthe Demetry is a Material Science professor at Worcester Polytechnic Institute. In her journal article, “Understanding Interactions Between

Instructional Design, Student Learning Styles, and Student Motivation and Achievement in an Introductory Materials Science Course" she examines the effectiveness of a trial and error method using the Classroom Performance System (CPS) and interactive learning. At the end of the class students rated the CPS as promoting thinking and active learning 3.56 on a 4.0 scale. The study showed that the CPS engaged the students by having them respond to a question that they experienced visually, answer using their hands, receive the percentage of answers from the class, discuss their choices with classmates in small groups, and then answer the question again. The CPS is a typical "think-pair-share" problem solving tool which engages all types of learners as discussed in the VARK program, which may be the reason why it is so effective.

2.6 Advantages of Hands-On Learning

Interactive museum programs are not only measured by entertainment value; these programs also have educational goals to fulfill (Caulton, 1998). The philosophy behind educational, hands-on learning originates from psychologists such as Jean Piaget, whose theory says that children learn from interacting with the environment around them. By adding more hands-on activities within the curriculum, teachers are more likely to see a lasting impact from their lessons. Educational settings following a science curriculum benefit from this technique, which is rapidly emerging in science museums around the world. A hands-on exhibit allows visitors to effectively learn the material in a new and exciting way.

The connection students feel to the subject through hands-on interaction is a vital aspect of the activity. Interactive exhibits are presented in an informal environment where students can be comfortable, rather than constrained in their mundane classrooms. Through the interaction, the students understand the topic quickly and are willing to learn more about it. Sometimes students even learn without realizing they are doing so. By entering into this form of learning, students are able to visualize the realities of science in the world outside their classroom (Zoldosova and Prokop, 2006). Young students, who tend to have short attention spans, do not lose interest in the topic or the curriculum because they remain involved and interested in the exhibit.

Museum educators carefully design and develop hands-on exhibits to have clear educational goals and be able to reach a variety of audiences. A good interactive exhibit will appeal to a variety of age levels and learning abilities. The educational information in traditional "hands-off" museum displays typically is gained by reading the description about the artifact behind the glass case. The hands-on exhibits teach the same information as the traditional displays, yet students are more inclined to pay attention and want to learn from them. Most well-designed interactive exhibits stress the importance of educational benefits when identifying and clarifying objectives and methodologies (Caulton, 1998).

Some psychologists, such as Richard Gregory, believe that these exhibits are mostly play and do not have as much educational value as a classroom setting. (Gregory, 2001) In Piaget's theory, however, children learn most when they are at play. Through stimulating interaction, the students will learn the curriculum as it comes most easily to them. Psychologist Howard Gardner believes similarly in his theory, which states that hands-on activities are "playgrounds for the mind." Within in this unstructured and informal learning environment, Gardner believes, children learn at their own pace, creating their own understanding. Although the exhibits are a fun atmosphere, the visitors retain and use the information learned while taking part (Caulton, 1998).

Students learn in a variety of ways. Hands-on exhibits target all four of the learning styles of younger children whereas a formal learning environment does not. For example, a student who is an experimental learner, one who learns by trial and error, may do poorly in a classroom setting. A formal learning environment, with exams and homework, does not always accommodate for trial and error learners who may need a second chance. Most hands-on exhibitions allow students to learn from their mistakes and different abilities and intelligences (Reiff, 1992).

2.7 Outreach Programs

Recognizing the growing shortage of individuals trained in science and engineering, many organizations around the world have become engaged in a variety of efforts to encourage students to pursue college degrees and careers in the various scientific fields. It is generally accepted that providing students with experiences in science early in their education is vital for creating a positive attitude towards science (Bruce, Bruce, Conrad, Huang, 1996). In the 2003 Trends in International Mathematics and Science Study survey, results show that by the 8th grade only 57% of the world's students were interested in and valued science education. The same study also reveals that only 12% of total instructional time at the elementary level is devoted to teaching the sciences (Chrostowski, Gonzalez, Martin, and Mullis, 2003). These statistics highlight the need for supplemental education to stimulate interest in the sciences.

In an effort to encourage greater student interest in the sciences, programs are being developed by educational institutions such as universities as well as professional organizations and museums, to aid schools in teaching science. These informal programs are typically tailored to the formal state and national curricula already in place, reinforcing the educational training students receive in school. Outreach programs are developed by first establishing a clear set of objectives (Martha Cyr, personal communication, November 14th, 2007). These objectives serve as a basis around which the program is created. Being precise in establishing objectives is not only important so that the program adheres to what is meant to be accomplished, but also so that the objectives serve as a tool to be later used as a post evaluation of the program. Once the set of objectives is defined, other aspects of outreach programs such as program type, funding, program duration, and learning style can be considered.

Examples of educational outreach programs can include professionals visiting a classroom, a traveling science exhibit, or providing activities and hands-on materials for teachers. There are common concepts that can be shared in developing any type of educational outreach program. Developers should base their programs on existing approaches and resources. Having an understanding of the students' current knowledge of the subject matter is very important. This will help in shaping key concepts to be conveyed and formulating the tools for learning around them. Programs working with younger students should especially value the teachers' ability to manage a classroom in order to maintain focus on the program and minimize distractions. Programs should also focus on engaging students by using resources to which they can relate. Students should be able to make connections to the material being covered (M. Cyr, personal communication, November 14th, 2007).

Dolan, Soots, Lemaux, Rhee, and Reiser (2004) discuss the development strategies of successful outreach programs. These authors evaluated their outreach program through informal interviews with sixteen scientists, teachers and outreach program professionals. The study observed the goals, motivations, methodologies, anticipated outcomes and evaluation strategies used to determine the elements of successful outreach programs. Identifying an audience and their needs and resources is described as the first strategy for development (Dolan, Soots, Lemaux, Rhee, and Reiser, 2004). This involves considering the needs of all involved stakeholders including teachers, students and informal educators. Getting teachers involved in program development and implementation is also a distinguishing aspect of successful efforts.

> "By involving teachers early and often in program development, one can reduce the risk of developing a program that is irrelevant and, therefore, unused by schools. Teachers ensure that outreach efforts are practical: the lessons developed are cost effective and easy to distribute. More importantly, however, teachers remind us that lessons must be engaging to students by involving them directly in the lessons and by being relevant to their everyday lives." (Dolan, Soots, Lemaux, Rhee, and Reiser, 2004)

Education and public outreach providers can support the goals of state and national science standards rather than view them as constraints. (Laursen, 2006) The article entitled "Getting Unstuck: Strategies for Escaping the Science Standards Straitjacket," presents effective strategies for developing K-12 outreach programs that both support and benefit from National Curriculum standards. Using inquiry-based teaching and learning as a strategy "requires that people identify their assumptions, use critical and logical thinking, and consider alternative explanations." (Laursen, 2006) This approach requires that students be posed scientific questions, then observe and evaluate the evidence, and then communicate and work with one another in an attempt to answer the question. Applying this strategy to interactive outreach materials can be very effective, as they can be used as stimuli and facilitate engagement for investigation of the inquiry. Materials can also be used as evidence to support an argument and devise an explanation. Laursen cautions that a common mistake made when using the inquiry strategy is that programs will use inquiry in a context that is too narrow for students to take a broader view and relate to their own investigations. This concept segues in to the next strategy of fostering connections to additional fields. Expanding the range of content in a program will help provide a more well-rounded educational experience and lead to new opportunities of interest for students. Seeking advice from experts in the program field is a cost effective way to gain insight and a better understanding of subject matter. This includes interviewing curriculum developers as well as scientists and individuals involved in higher education. Information derived from these sources may spark new ideas for material and facilitate the development of a more comprehensive program. Laursen's ideas provide interesting and useful methods for developing outreach programs that benefit from and support science standards.

What outreach programs can hope to achieve depends on the goals of the organization initiating the program. Scientifically-oriented outreach programs can serve as effective tools for educating and sparking interest in science. "Most classrooms still need better science materials and equipment, as well as support for teachers in content instruction and use of new technologies." (Bruce, Bruce, Conrad, and Huang, 1996) The authors contend that outreach programs can serve as a valuable method for addressing these issues. Conducted by the College of Education at the University of Illinois, the study focuses on a program called SEARCH (Science Education and Research for CHildren). SEARCH is led by science students at the University who travel to local elementary school classrooms. The outreach program utilizes collaboration between a teaching and learning model designed to enhance understanding of and excitement about science. To accomplish this, the program combines activity-based learning with appropriate content and expertise. Over the past four years since being implemented, the program has reported great success with an overall desire for expansion by all parties involved. One of the main principles of SEARCH is that "learning cannot be repeating the knowledge supplied by others, but rather, constructing meaning based on interaction with the world." This emphasizes the importance of engaging students in hands-on activities and experiences that can be provided by specialized outreach programs.

Gauging the success of outreach programs can be separated into two categories of long and short term goals. Assessing the immediate benefits of outreach programs can be achieved through observation and evaluation. Conversely, judging the ability of outreach programs to achieve long term results is mostly based on faith as there is little research that supports their long-term effectiveness (Laursen, Liston, Thiry, and Graf, 2006). The objectives these programs hope to accomplish span a very long period of time and it is very hard to predict their success. While the greater cause of science outreach programs may be to increase student interest in science in general, the goals of each program may vary specific to their own objectives. Very few studies have been conducted that provide a comprehensive analysis on the results of outreach programs. The methodologies for studies conducted on outreach programs are not only constrained by time and money, but also by the difficulty of quantifying their success. The vast numbers of external factors that can affect the results of an outreach program make them very difficult to accurately judge. These factors include age, gender, economic status, educational background and many other variables that restrict the ability to observe a homogenous group. Surveys that attempt to report on the success of an outreach program cannot be certain of pinpointing what actually caused the change. Perception of success is almost always based on interpretation by the stakeholders involved in the program (Laursen, Liston, Thiry, and Graf, 2006).

A study conducted by the Biological Sciences Initiative at the University of Colorado, Boulder, attempts to address as many issues as possible in assessing the effectiveness of a short-duration outreach program. The study, published in *Life Sciences Education,* is entitled “What Good Is a Scientist in the Classroom? Participant Outcomes and Program Design Features for a Short-Duration Science Outreach Intervention in K–12 Classroom.” The study limits as many variables as possible by following a well-established outreach program. The program bases their idea of success on the notion that developing interest and enthusiasm about science will create a different attitude towards it, thereby increasing the likelihood of students pursuing scientific careers later in life. “Scientist in The Classroom” reaches about 15,000 students and 270 teachers a year. To gauge the success of this program, both teachers and students are interviewed, as are program members, on their perceptions of the effects the program has. The study found that 88% of teachers and 92% of program members felt that “Scientist in The Classroom” “enhanced interest and engagement…As evidence for these benefits, teachers reported student behaviors such as concentrating on the activities, asking questions, and stating their interest. No teachers reported lack of engagement or interest.” The study goes on to further qualitatively analyze and attribute other benefits such as new views and relations to science and highlighting the gains achieved by the outreach program. The authors concluded that if the program, “Scientist in The Classroom,” maintains a strong structure and is effectively run, it can have “a positive impact on students' interest in science and thus their eagerness to learn it."

2.8 National Curriculum

Following the Education Reform Act of 1988, a nationwide curriculum for early education state schools was established in the United Kingdom. Regarded as "one of the most important single pieces of education legislation in England, Wales and Northern Ireland" (Winch, 2004), it was passed to ensure every pupil had the same opportunities to learn and achieve. The National Curriculum is divided into four Key Stages, each covering a wide array of subjects. There are also nine levels, the ninth being for exceptional students, within each Key Stage. These levels set standards for learning capabilities of pupils. Children between the ages 3 and 5 will enter into Key Stage 1 at the beginning of their primary education. In Key Stages 1 and 2, all pupils are required to study the subjects English, mathematics, science, history, art, music and Information Technology. Key Stage 3 is taught to children in their 7^{th}, $8^{th,}$ and 9^{th} years in school. Key Stage 4 is taught during the last level of early education when students are between the ages of 14 and 16. The curriculum expands to include design technology, religious education, career education, and foreign language. The primary focus during Key Stage 4 is preparation for the General Certificate of Secondary Education (GCSE) exams.

GCSE courses begin during year 10 and final exams are then taken at the conclusion of year 11. There are five examination boards in the United Kingdom that offer the GCSE exams; however, all of them are regulated by the Quantitative Curriculum Assessment (QCA) group. The QCA is a company which assesses the National Curriculum and provides recommended standards as a guide for teachers. In addition to regulating the GCSE examination boards, the QCA also keeps the National Curriculum under constant review and evaluates its appropriateness to the ever-changing standards of learning in today's society.

The National Curriculum aims to "promote pupils' spiritual, moral, social and cultural development and prepare all pupils for the opportunities, responsibilities and experiences of life." (National Curriculum Online) The United Kingdom government does so by establishing standards for each individual required subject taught in the varying stages. The standards are used to assess improvement and progress among pupils, parents, and teachers.

By appealing to a variety of learning styles, outreach programs supplement areas of the National Curriculum in which students who struggle in a typical classroom setting are falling short of the standards. The greater degree of flexibility in the formatting of these programs allows educators to meet the requirements of the National Curriculum in more exciting and interesting ways than a typical classroom lecture.

2.9 Material Science

The topic of material science, within the subject of science and technology, is important in all Key Stages. As early as Key Stage 1, pupils are taught a range of properties in order to distinguish the difference between varying materials. They will also be taught the properties of material changes, such as freezing water and baking clay. A strong focus on material science occurs during Key Stage 3. Pupils gain a knowledge and understanding of the nature and behavior of materials and study their chemical and physical changes (National Curriculum in Action). The curriculum stresses creative thinking in order to make scientific predictions and to back them up with experimental evidence. Essentially, the study of material science looks at what everything is made of, all the way down to the atomic-level structure. It spans from polymers to metals among other topics and is also responsible for developing them for specific uses.

A career in material science can be pursued after a four-year college degree in majors including mechanical engineering, civil engineering, biomedical engineering, materials science, chemistry or physics. Today, careers in the material science industry can range from textile fabric production to designing artificial hip joints. To increase interest in pursuing such careers, the United Kingdom Centre for Materials Education was formed as part of the Higher Education Academy in October 2004. The centre "exists to support and promote high quality education in materials and related disciplines, by encouraging and coordinating the development and adoption of effective practices in learning, teaching and assessment" (United Kingdom Centre for Materials Education). The centre provides students with guidance on what material science related opportunities are available, as well as guides for professors and parents. Similarly, the mission of the newly-opened VisionWorks Material Science Learning Zone is to "stimulate and excites pupils' curiosity about phenomena and events in the world around them." (http://www.royalarmouries.org/extsite/view.jsp?sectionId=3553) Sponsored by the Royal Armouries at the Tower of London and Bayer Material Science, this learning center also aims to educate and excite students about material science.

2.10 Conclusions

Museums preserve cultural and historical heritage and serve as centers of education and research. They supplement formal education with exhibits and programs, both within the museum itself and by traveling to schools. By allowing visitors to learn informally, museums and their outreach programs can appeal to many different learning styles and address areas of the National Curriculum left lacking by standard formal education. This will become especially important given the recent declining interest in scientific studies in the UK, which if allowed to continue will lead to serious societal problems.

3. Methodology

3.0 Introduction

The objective of this project is to create all the necessary guidelines, experiments, and procedures for a polymer-based material science loan box which will supplement the VisionWorks Material Science Learning Zone at the Royal Armouries. The loan box will complement the National Curriculum at Key Stages 3 and 4 while relating the program to the Royal Armouries' collection. The loan box, using experiments and hands-on materials reinforced with comprehensive explanations, will provide a stimulating educational experience for students. Linking the loan box with the collections of the Royal Armouries will give students a glimpse at the importance of materials both past and present and would ideally encourage further study of the subject.

3.1 Continuation of Literature Review

Throughout the entire project, additional literature and other relevant materials will be collected in order to gather enough background information to successfully design the loan box. A solid foundation in material science is necessary to fully understand the experiments and information included in the box. Previous outreach programs will serve as additional references for the design of the program. The project team will research successful teaching methods and lesson plans in order to develop an effective program. Most of the preliminary project research will be conducted at Gordon Library at Worcester Polytechnic Institute as well as other local libraries and museums. Upon arrival at the Royal Armouries, the project team will seek out additional references, including information on previous outreach programs and traveling exhibits conducted by the Royal Armouries and the London Science Museum.

3.2 Interviews

As part of the project preparation and research, the group will conduct interviews with various individuals who have experience in the fields of materials science, outreach programs, and middle-school education. The interview process will serve as a means of both gathering useful information that could not be found in the literature and networking.

Before interviewing, the group plans to outline information that it needs to obtain from the interviews, mainly regarding outreach programs – their importance, how to go about creating them, and what constitutes an effective program. Education will also be a major area of focus. The group will then identify individuals who could potentially answer the general questions on these topics, and depending on the individual's area of expertise, more specific interview questions will also be formulated. Preliminary interviews conducted in the US will act as a trial for the question and topic lists, which will then be revised for UK interviews.

Because no one in the group has any prior experience with outreach programs, be it creating or implementing them, this will be the first and most important area to be addressed. Interviews will be conducted with staff members at WPI, the London Science Museum, and the Royal Armouries in both formal and informal interview settings. All of these individuals have experience with outreach programs in some way. The majority of questions will address topics such as maximum possible duration of a session, balance between lecture and hands-on activities, and effective strategies for presenting information. From these interviews the group hopes to learn strategies for designing the outreach program and how to make it as effective as possible.

The other major topic to be focused upon in interviews is education, especially at the middle-school level. Through interviews with professors at WPI, the group hopes to learn about effective teaching methods. The majority of the education-focused interviewing will likely take place in London, with Royal Armouries staff and teachers visiting VisionWorks. Many of the group's questions for Royal Armouries staff are going to revolve around the requirements of the National Curriculum and how best to fit the program to those standards, as this system is very different from typical US curricula. Also, the group will be asking about past Royal Armouries programs – strategies for teaching, what does not work, and what has worked best. Questions for visiting teachers will focus more on proposed experiments and activities for the loan box, with the intention of getting feedback on these ideas and how likely they would be to engage a class.

Throughout the entire process, a semi-structured format will be used in order to focus the interview so that relevant information is obtained while still allowing flexibility in the conversation. Interviews will likely range in duration from fifteen minutes to approximately one hour. Prior to each interview, group members will be named as designated note-takers, and after the interview is completed the group will review these notes and determine the best direction to take for follow-up communication.

3.3 Ideas for the Outreach Loan Box

The main focus of the loan box is on modern-day polymers and relating them to body protection, both modern and historic. Hands-on materials such as photos of historic armor and a modern riot vest will be presented through teacher demonstrations, and the box will also include experiments and PowerPoint presentations. Initial experiment research will be conducted on the internet and through interviews with outreach professionals. While in the US, the project team will research sites such as www.teachengineering.com to get ideas for experiments to include in the loan box. All of the programs on this site follow a curriculum from one or multiple states in the US. Once in London, the project team plans to conduct additional internet searches with a better idea of what experiments would be needed in the box. These experiments will be chosen to keep the students interested in learning about polymers while still relating them to body protection and the Royal Armouries. For example, one experiment the group considered involves students making a corn flour and water mixture that yields a shear thickening fluid. The substance remains in liquid form until pressure is applied, at which point it becomes a solid. This experiment, while fun and exciting for the students, can also be used to relate polymers to smart materials currently being developed for body protection. During this experiment, the teacher could explain to the class that the same concept is being developed in body armor to stop a bullet from piecing it upon impact. Making experiments the core of the program will keep lecturing to a minimum and therefore keep students more engaged and interested in learning about material science.

Educating the teacher on the loan box program will also be a major aspect of the program design. Ideas for exactly how to accomplish this range from an in-house demonstration at the Royal Armouries to a short DVD that a teacher could watch at home to learn everything they needed. The team will also consider designing a teacher's guide that includes everything a teacher would need to know before integrating the loan box into their curriculum. This option is the most inexpensive and simplest way to include all necessary information such as experiment procedures, curriculum standards and hazard warnings.

3.4 Supporting the National Curriculum

When designing lessons for the loan box, the project group intends to follow the National Curriculum standards for material science as provided on www.ncaction.org.uk. To do this, the team will review the standards and design different activities that would adhere to as many standards as possible. The team realizes that if the loan box covers a significant portion of the material science curriculum, it will be more useful for and attractive to teachers. The material in the loan box will be flexible in order to meet the teacher's needs (i.e. contain enough information and activities that the teacher could then choose which they wanted to use) or cover material specifically determined to be lacking in the curriculum. In the teacher's guide, a list of all activities will be included along with which curriculum standard(s) they apply to, allowing teachers to pick and choose what would work best with their current lesson plans.

The principal age group for which the loan box will be designed is Key Stage 3, but the material will be adaptable to Key Stage 4 as well. This will be accomplished by designing different activities for different age groups, assuming time and money allow the group to do so. While at VisionWorks, the project team intends to speak briefly with teachers visiting the education center regarding what they would expect from the loan box. Obtaining insight on what teachers find useful for their classes will help immensely when choosing topics of study for the box. Also, using evaluations from classes visiting VisionWorks, the group hopes to get a general idea on what projects and experiments are most effective from both the teachers' and the students' points of view. The team will investigate whether the Royal Armouries already has a collection of feedback on VisionWorks exhibits, and if such evaluations exist then the team will analyze them and apply that information to the program design.

3.5 Evaluation of the Loan Box

The team realized very early that having the loan box ideas evaluated by the target audience would help create a well-rounded outreach program. By working with the Royal

Armouries and the London Science Museum's education department, the group hopes to learn how these organizations typically test and evaluate new exhibits in their museums. The project team will then formulate a general testing process. This general, two-step process will evaluate the effectiveness of the loan box's experiments by focusing on summative evaluation. The first step is to test a few prototype experiments in small groups that visit the museum. This research will focus specifically on the effectiveness of the experiments or major activities in the loan box. If possible, the team will set up a small area in VisionWorks to test the experiments on visitors. Following the demonstrations will be a discussion session in which the team will let students ask questions and provide them with answers. This will also give the project group time to informally survey the students and visitors, which will help to assess the experiments or activities. The demonstrations will be done in smaller groups of about five people which will enable the team to receive more open-ended feedback and discussion. This will also give team members a chance to ask the students if they have any other questions about material science left unanswered by the presentation. This information can then be implemented in the next version of the prototypes. It has been suggested that a trial and error method is most effective with outreach program prototypes, i.e. presenting the program to a class for a trial run. This gives the program designer the chance to find out what is effective and what needs to be edited before finalizing the program (M. Cyr, personal communication, November 14th, 2007).

Ideally, for the second step in the evaluation process, the team will test the experiments using summative evaluation in a closed classroom setting with Key Stage 3 classes visiting the museum. This will give the team a chance to present the loan box in its entirety to the targeted audience. As a class, the students will be given a short presentation and demonstration on some of the possible experiments and then be given a survey in which they can evaluate the experiments. The surveys will be used to determine any changes that may need to be made before finalizing the loan box design. Depending on the schedules of these groups, there will a presentation of roughly twenty minutes with 80% focusing on the actual experiments and 20% on discussion and feedback on the experiments. The team will allot sixteen minutes for the experiments (including a two-minute introduction) and four minutes for feedback/survey. This time frame may be modified upon consultation with the Royal Armouries regarding similar programs they conduct.

The presentation will start with a quick introduction and brief overview on material science and its role at the Royal Armouries. This is to make the key concepts clear to the students so that they understand the objectives of the presentation before it begins. This introduction will then be followed by demonstration of a brief experiment or two which the students can tie to their own lives, bringing forth the knowledge they already have on material science. The objective is not just to teach students about material science, but also to engage them in the material science already present in their lives. The team wants the students to see the social relevance of material science, and recognize that it makes a difference in the world, which is frequently the goal of similar outreach programs (C. Demetry, personal communication, November 19th, 2007).

Each student from the classes will be given a quick survey following a presentation of the experiments that will potentially be a part of the loan box. The survey will consist of five to seven Likert scale questions, such as, "On a scale of one to six, how entertaining did you think the bicycle helmet activity was?" The answers will be used in order to receive quick results from closed-ended questions, while the smaller group experiments and evaulations will be used to receive open-ended information. This overall two-step process will give the team both qualitative and quantitative results using summative evaluation. The team plans to make the survey short enough so that students can fill it out quickly and not lose interest or rush to finish. It would be ideal to know the demographic types of learners in the audience, but such considerations would make the survey too long.

The team plans on working with the education department at the Royal Armouries in order to gain a sense of how they test and evaluate their exhibits at the museum. The Royal Armouries does not have any relevant outreach programs that the project group can mimic, but it will be useful to follow the process they use to test their in-house programs. It will also be beneficial for the team to talk with the London Science Museum, which offers a broad range of outreach programs. This will give the group an understanding of how they formulate their programs.

3.6 Analysis of Results

Being able to analyze the results and feedback provided by the teachers and students will be very important in evaluating the success of the loan box. If feasible, the project team will be looking at results of two separate surveys from teachers and students to gauge which areas of the loan box need improvement and which are effective. The analysis of these results will provide the team with information to make the necessary revisions to the loan box.

The first part of analysis is looking at the data qualitatively. Each survey will include a number of open response questions for the teachers and students to provide feedback on each experiment from their respective points of view. Possible questions for teachers may include "Did you feel the loan box was educational while still being fun for students?" and "How would you improve the program?" Student questions would include "What did you enjoy most about the loan box program?" and "Did you feel the procedures were easy to follow?" A qualitative approach allows the team to look at the data subjectively, and seek to understand the nature of the responses.

In addition to looking at the data qualitatively, the team will also observe and collect quantitative information via a survey, which will have a number of questions designed to numerically rank certain aspects of the experiments and activities such as educational value and degree of enjoyment experienced by the students. This quantitative analysis will be focused on a target group as a whole, rather than the smaller individual teams used in the group's other evaluation methods. It will serve as a preliminary basis for feasibility analysis because the team will be able to determine relative experiment effectiveness by comparing the scores each experiment receives to those of the other experiments. Using a quantitative analysis will also enable the team to quickly see whether experiments are either very poor or effective by looking at their scores.

Using both methods of analysis will help limit any biases that might have arisen. Given the limited sampling size it will be important to carefully examine all feedback received from both the students and the teachers. As a team, we will also be considering any limitations of our survey. Due to time constraints it would have been impossible to include every question that may be relevant in our surveys.

3.7 Cost

Aside from determining the effective resources and materials within the loan box itself, the group will need to investigate sources to provide funding for the program. The Material Science Learning Zone is co-sponsored by both the Royal Armouries and Bayer Material Science. The project team will look into working with both of these companies as a starting point for supporting the program. Professor Demetry notes that local companies are often interested in funding programs that support education in their local communities (C. Demetry, personal communication, November 19^{th}, 2007). The team also intends to make a list of 'replaceable' and 'reusable' materials in order to know which materials must be replaced after each use of the loan box. The project team's main goal is to keep the loan box as cost-effective as possible. For example, to minimize printing and shipping costs, the literature included in the box may be sent out digitally on a CD. Once the program design is underway, a detailed budget will also be created that includes the experiments proposed for the box, estimated cost of replacing disposable materials, and the cost of delivering the box to the schools. Working budgets from pre-existing outreach programs will serve as a primary reference off of which the loan box budget will be based.

4. Results

4.1 Choosing the Loan Box Activities

When investigating possible activities, the project team's main concerns were that each one provided hands-on learning along with a relation back to the Royal Armouries. The team selected the activities with the notion that they would engage students as well be something the students have never done. The activities must also be able to segue into relevant educational principles of material science that align with the National Curriculum. Linking the activities to the National Curriculum is necessary to provide justification for teachers to implement the program. Simplicity was a major consideration in choosing activities. For the program to stand alone and require minimal assistance from the Royal Armouries, teachers must be able to perform and supervise the program correctly. One final concern was on the safety of the experiments. Many experiments, especially in chemistry, require the use of chemicals that can be a serious danger to students, inflicting serious injury if mishandled.

Once clear criteria were established for the program, the team began to research and investigate actual activities to include in the loan box. The project team first turned to the internet, specifically educational material science websites. One of these databases, teachengineering.net, was suggested to the team during an interview with Martha Cyr. Another useful website, www.practicalchemistry.com, provided the project team with several experimental procedures and also linked the activities to the National Curriculum standards covered by the experiment.

Consulting with the education department at the Royal Armouries aided with deciding between activities and confirming that they would be useful for the outreach program. These individuals' experience in the VisionWorks Material Science Learning Zone helped provide the team with insight on what has already been developed and taught to Key Stages 3 and 4. The education staff also provided the project team with *How to Fossilize Your Hamster*, a book containing many relevant science experiments. This book was recreationally focused and the experiments tended to be fun, relevant to real life, easy, inexpensive, and safe.

Teachers visiting VisionWorks also proved to be valuable resources for selecting activities. Several brief, informal interviews with these teachers helped the project team confirm that the experiments chosen had never before been conducted by most students. For example, the team had initially planned to include making slime as an experiment; however, several teachers stated that this was something which many students using the loan box would already have done and so the team pursued other options.

4.2 The Loan Box Activities

After careful consideration, the activities the group decided upon for inclusion in the loan box were: "Balloon Kebabs," "Hands-On Polymers," "Makin' Casein," "Secret State," "Protecting the Future," and "Melting Polystyrene." These activities serve as the basis from which supplementary materials were developed in order to diversify the loan box program and make it appeal to a broader audience.

"Balloon Kebabs" involves a demonstration that displays the characteristics and properties of polymer molecules. A balloon is blown up about halfway and sealed. A skewer tipped with cooking oil is then carefully pushed through the balloon which does not pop. The same technique is then used on a plastic bag filled with water. This demonstration is designed to be an "attention-grabber" at the beginning of the program. It introduces the concepts of polymer chain structure and provides segues into further discussion of polymers and their properties.

"Hands-On Polymers" is a presentation and demonstration in the loan box program. The activity consists of several different polymers and an accompanying PowerPoint presentation filled with facts and interesting applications of each polymer included. This activity is designed to show students the properties of different polymers and how they are used. It focused on the three polymers that are tested in the Science GCSE, four polymers that the students will encounter in everyday life, and two polymers that are specific to the Royal Armouries and modern day body protection.

"Makin' Casein" is an experiment performed by the students in groups. It involves making a polymer (i.e., casein) by heating milk and then adding vinegar, an acid. Because casein is not soluble in acid, it forms clumps of a natural plastic that the students can then strain out and mold to a desired shape. This activity helps explain and illustrate principles behind the formation of long-chain polymers, chemical reactions, and properties of acids. It can be extended to Key Stage 4 by adding sodium hydrogenate and changing the procedure slightly to produce a similar result.

“Secret State” is also intended for groups of students. Students mix corn starch and water in precise proportions to create a shear-thickening liquid. The resulting compound holds shape when compressive forces, such as rolling a small amount of it between two hands, are applied but returns to liquid form as soon as that force is removed. This experiment introduces the concept of ‘smart’ materials, materials that can alter their properties based on external stimuli. Smart materials are being extensively researched for their use in a variety of industries, armor being one of them. As such, the activity can be tied in with the Royal Armouries and its collections of armor from past to present.

“Protecting the Future” is an activity that combines education on traditional armor of the past with modern polymer design and technology. The exercise begins with photos from the Armouries’ collections and discussion on the design of historic pieces of armor. Using everyday household polymers, students will then design their own ‘futuristic’ armor. By encouraging students to consider properties such as flexibility, comfort, and degree of protection, this activity teaches the concepts of tensile strength and the strength versus flexibility of tightly packed molecules. Students can compare their own designs with real armor, examining the similarities and differences and explaining why they chose to design their armor the way they did.

“’Melting’ Polystyrene” is an experiment in which students investigate why Styrofoam appears to melt when it comes in contact with acetone. It explores the properties of polymers with relation to the bonding of long chains of molecules. Styrofoam is made from expanded polystyrene, which has looser molecular packing than other forms of polystyrene. Acetone penetrates the empty spaces between molecules and forces the air out, altering the properties of the polymer. The experiment also helps to explain characteristics of polarity. Both acetone and polystyrene are non-polar; therefore the polystyrene is soluble in the acetone.

While developing the loan box, the team made sure that all of the VARK (Visual, Aural, Reading/Writing and Kinesthetic) learning styles were targeted. The activities in the program were selected to appeal to all learning styles, thereby providing a well-rounded outreach program for the Armouries.

4.3 Relating Activities to the National Curriculum

The activities that the team chose for the loan box directly tie in with the National Curriculum for Key Stage 3, with extensions for that of Key Stage 4. They were carefully chosen this way so that teachers would not have to set aside lessons in order to use the program. The program includes and supplements material which teachers are already required to teach. The activities were written for learning levels three to eight in order to reach as many students as possible.

In order to reach an even wider array of students, the team also wrote extensions for each experiment so that they fulfilled requirements for Key Stage 4. At the end of Key Stage 4, pupils take a General Certificate of Secondary Education (GCSE) exam. Several examination boards make suggestions as to what students should be taught from the National Curriculum in order to pass this exam. Though not official requirements, these suggestions often serve as guides around which teachers form their curricula. For the loan box program, the group researched these companies and their suggestions to the National Curriculum. As previously discussed, there are four major GCSE examination boards: Qualifications and Curriculum Authority (QCA), Oxford Cambridge and RSA Examinations (OCR), Assessment and Qualifications Alliance (AQA), and Edexcel. The following table shows each experiment and the examination board standards they fulfill.

Experiment	Examination Board Standards
Balloon Kebabs	**Key Stage 3:** **QCA** Science Standards: Unit 8E (atoms and elements) **Key Stage 4:** **OCR** Science in the 21st Century: Science Suite Science in the 21st Century: Chemistry A Chemistry – Structure and bonding **QCA** The properties, characteristics, and features of materials that affect: ○ ability to be shaped and formed ○ ability to be treated ○ ease of handling ○ availability, form and supply
Polymer Hands-On Demonstration	**Key Stage 3:** **QCA** Science Standards: Unit 8E (atoms and elements) Unit 7K (forces and effects)

<table>
<tr><td></td><td>D&T Standards:
Unit 08aii (Exploring Materials Focus: Resistant Materials)

Key Stage 4:
OCR Science Guide Sections:
Chemistry – Structure and bonding
AQA:
Unit Chemistry 1:
11.1 – How do rocks provide building materials?
11.3 – How do we get fuels from crude oil?
11.4 – How are polymers made from oil?
Unit Chemistry 2:
12.1 – How do sub-atomic particles help us to understand the structure of substances?
12.2 – How do structures influence the properties and uses of substances
12.3 – How much can we make and how much do we need?
12.5 – Do Chemical Reactions always release energy?
QCA:
Engineering materials and the properties in the following groups:
Polymers
Composites that combine the properties of different materials
The properties, characteristics and features of materials that affect:
Ability to be shaped and formed
Ability to be treated
Availability, form and supply
EDEXCEL:
Module 4: Chemistry in Action
Topics:
Crude Oil
Plastics
Types of Chemical Reactions</td></tr>
<tr><td>Makin' Casein</td><td>Key Stage 3:
QCA
Science Standards:
Unit 8F (compounds and mixtures)
Unit 9H (using chemistry)

Key Stage 4 (GCSE Standards):
GCSE Standards:
OCR
Chemistry – Structure and Bonding
The Unique Properties of Water – Electro negativity, exchange of electrons
QCA
QCA Engineering Materials – Polymers, Composites that combine the properties of different materials
The properties, characteristics, and features of materials that affect:
ability to be shaped and formed
ability to be treated
ease of handling
availability, form and supply
AQA</td></tr>
</table>

	• 12.5 – Do Chemical Reactions always release energy? • 13.2 What are strong and weak acids and alkalis? How can we find the amounts of acids and alkalis in solutions? • 13.4 How much energy is involved in chemical reactions? **EDEXCEL**: Module 4: Chemistry in Action Topics: • Enzymes
Secret State	**Key Stage 3:** **QCA** Science Standards: Unit 7F (simple chemical reactions) Unit 8F (compounds and mixtures) Unit 9H (using chemistry) **Key Stage 4 (GCSE Standards):** **OCR** • The Unique Properties of Water – Breaking and Forming bonds through condensation and evaporation **QCA** • Engineering Materials – Polymers, Composites that combine the properties of different materials • The properties, characteristics, and features of materials that affect: o ability to be shaped and formed o ability to be treated o ease of handling o availability, form and supply • Engineering processes: o Shaping and manipulation o Heat and chemical treatment • New technology used in and by the engineering industries o Modern and 'smart' materials and components • The Impact of modern technologies o Advantages and Disadvantages that the use of modern technology has brought to society • Engineered products: o Investigate a variety of engineered products that use modern technology **AQA** • 11.4 – How are polymers made from oil? • 12.1 – How do sub-atomic particles help us to understand the structure of substances? • 12.2 – How do structures influence the properties and uses of substances • 12.5 – Do Chemical Reactions always release energy? • 13.2 What are strong and weak acids and alkalis? How can we find the amounts of acids and alkalis in solutions? • 13.4 How much energy is involved in chemical reactions?
Protecting the Future/Nanomaterials and Smart	**Key Stage 3:** **QCA** **Science Standards:** Unit 7K (forces and bonding)

<table>
<tr>
<td>Technology</td>
<td>
D&T Standards:
Unit 07aii (Understanding Materials Focus: Resistant Materials) Unit 08aii (Exploring Materials Focus: Resistant Materials)
Unit 08bii (Designing for Clients Focus: Resistant Materials)

Key Stage 4 (GCSE Standards):
QCA

Engineering processes:

Shaping and manipulation
Heat and chemical treatment

New technology used in and by the engineering industries

Modern and ‘smart’ materials and components

The Impact of modern technologies

When engineering a product
On engineered products
On engineering industries
On stages in engineering a product
Advantages and Disadvantages that the use of modern technology has brought to society

Engineered products:

Investigate a variety of engineered products that use modern technology
Investigate the impact of modern technology on the design and production of a range of engineered products.

AQA

11.1 – How do rocks provide building materials?
11.3 – How do we get fuels from crude oil?
11.4 – How are polymers made from oil?
12.1 – How do sub-atomic particles help us to understand the structure of substances?
12.2 – How do structures influence the properties and uses of substances

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<tr>
<td>Melting Polystyrene</td>
<td>
AQA

Chemistry Section 1

11.1 – How do rocks provide building materials?

Chemistry Section 2

12.1 – How do sub-atomic particles help us to understand the structure of substances?
12.2 – How do structures influence the properties and uses of substances?

QCA (for GCSE engineering)

The properties, characteristics and features of materials that affect:

Ability to be shaped and formed
Ability to be treated

Engineering processes:

Shaping and manipulation
Heat and chemical treatment

OCR
GCSE Science Guide Sections:

Chemical and Material Behaviour
Structure and Bonding

Edexcel
Module 4: Chemistry in Action
Topics:
</td>
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</table>

	• *Types of Chemical Reactions*

Table 1: National Curriculum Standards and Suggested Curriculum Topics

4.4 Relating the Activities to the Royal Armouries

One of the key points stressed by the team's sponsor was that the experiments and materials included in the loan box must relate to the Royal Armouries. As such, the team chose activities that would relate not only to the National Curriculum, but also to the mission and goals of the Royal Armouries.

The first experiment, "Balloon Kebabs," was chosen as an introductory demonstration to intrigue the students and grab their attention. It involves piercing a balloon and a water-filled plastic bag with sharp objects and observing what happens – namely, that the balloon does not pop and the bag does not leak. This demonstration illustrates an important concept relating to armor. Armor must have flexibility and be able to withstand impact from objects large and small, sharp and blunt, at a wide range of velocities. The material from which the armor is made needs to be able to stretch and deform slightly even after it is molded into its final shape. This is especially important today, with armor being developed and made out of polymers. Without flexibility, any additional deformation or stretching would break the polymer chains that compose the material, leaving a hole in the armor or causing a chain reaction in which the entire piece shatters. Armor like this would not protect the wearer, nor could it be used again after being hit. Neither the balloon nor the plastic bag was stretched to its limit, and so the additional deformation and stretching required by poking with the sharp object could be tolerated without disastrous effects. In the past, when armor was made from metal, the armorer would often test the finished product by shooting it, leaving the dent in the armor to show that it worked. This was called "proofing" the armor.

The second experiment included in the loan box is "Makin' Casein," in which students mix milk and vinegar to "produce" a natural polymer. Casein is a protein, or natural polymer, found in milk products. By heating the milk and mixing it with the acidic vinegar, the students are able to get casein as a precipitate. It can then be dried and after some time molded into various shapes. Moldable polymers have become incredibly important in the armor and protection industry, especially with the introduction of materials such as Kevlar®. Using polymers that can be easily molded simplifies the manufacturing process and allows new, more effective types of protection to be made. For example, horse shoes can now be made out of polymers and can include a compartment for medicines to be delivered through the horse's hoof. These new shoes are more comfortable than typical metal horseshoes and are far easier to replace. Kevlar® body armor can be made for drug-sniffing police dogs to protect them when going into dangerous areas. By doing this experiment, students are also taught that polymers are not just man-made plastics, but also naturally occur in many forms in the world around them. This ties in closely with the Royal Armouries' VisionWorks exhibit, which aims to educate students about polymers and show that they are an important part of everyday life.

In "Secret State" students mix corn flour and water to create a dilatant (shear-thickening) fluid. Shear-thickening fluids are those which increase in viscosity with increasing applied force. The greater the force being applied to the fluid, the harder it becomes. Students can drag their hands through the fluid easily, but will find it very stiff when they try to poke it. The mixture can also be rolled into a ball, but once the rolling motion ceases the mixture becomes a liquid once more. This phenomenon is being incorporated into "smart material" armor, such as bulletproof vests and clothing for the police and military, and others in dangerous occupations. The guiding principle behind such armor is that it will instantly harden upon impact from a bullet or shrapnel or other objects, but otherwise be soft and easy to move in. A similar idea is in development for clothing: the fabric can be soaked in a shear-thickening fluid, and will become rigid when hit by a bullet. Otherwise, it will look and feel like normal clothing, with the exception of being slightly oily to the touch (http://www.aip.org/dbis/stories/2006/15201.html). The Royal Armouries sponsors a program called "No to Knives," aimed at reducing the number of young people carrying knives on the streets, which has become a serious problem in recent years. Developments in protection like shear-thickening fluid coating for clothes and Kevlar-lined hooded sweatshirts, or "hoodies" (one of which the VisionWorks center has as part of its collection), could help save lives.

Students are challenged in "Protecting the Future" to design their own armor out of everyday polymers. They are told to consider factors such as comfort, durability, flexibility, and safety in their designs. At the end of the activity, students will be asked to present and explain their ideas. The goal of this activity is to get the students in the mindset of an armor designer. Students must weigh the importance of each factor and decide which is the most crucial to their armor. In another part of the loan box program they will be presented with pictures of armor from the Royal Armouries' collection. This collection spans centuries of history, from Norman times right through to modern day. Combining the pictures with this design activity also shows students how armor has changed through time to adapt to different weapons and new technology.

4.5 Testing the Experiments

After writing the appropriate instructions in the teacher's guide, the project team began testing each individual experiment. The tests took place in the VisionWorks Material Science Learning Centre on January 25, 2008. The project team hoped the tests would ensure the instructions are easy to understand and would confirm the experiments work properly.

The demonstration, "Balloon Kebabs" would be considered a success if a lubricated skewer poked through a half-inflated balloon from the bottom to the top. Also, the second part of the demonstration involved poking a sharpened pencil completely through a re-sealable plastic bag filled three-quarters of the way with water. If done successfully the balloon will not pop and water will not leak out of the plastic bag. Fortunately, both demonstrations worked successfully on the first trial. Although the project group was concerned about the demonstration not working well for instructors on the spot, after two more trial runs, the group concluded that both demonstrations could easily produce successful results if the instructions were carefully followed.

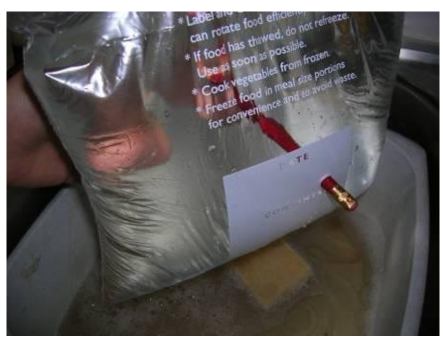

Figure 2: Pencil poked through plastic bag filled with water

The first student experiment tested was 'Melting' Polystyrene. When acetone is placed on the expanded polystyrene (Styrofoam) cup, it should break down the polystyrene into ‘goo.’ The VisionWorks lab had an acetone-containing nail polish remover which the team used as a substitute for pure acetone. No reaction occurred when the cup was placed in this solution, which the project team hypothesized was because the nail polish remover was a highly diluted solution of acetone. After obtaining pure acetone, the experiment was repeated. It worked as expected, with the cup melting down into a gooey substance.

The next experiment to be tested was ‘Secret State.’ The experiment, when performed correctly, should result in a dilatant material created by a mixture of corn flour and water. This simply-executed experiment was inexpensive and produced excellent results. The corn flour and water mixture appears to be a liquid in the mixing bowl. However, once pressure is applied to it, such as a stirring spoon, it instantly begins to harden. Members of the project team took a handful of the mixture and worked it into a solid ball in their hands. When the hand opened, the ball instantly melted back into a liquid and dropped back into the bowl. The project team concluded that the experiment, though messy, will be exciting for students.

Figure 3a-b: Corn flour mixture as a solid and liquid state

The final experiment tested was 'Makin' Casein for KS3'. By heating milk and adding an acid, vinegar, a precipitate (casein) was formed (see Figure 2).

Figure 4: Producing the casein

This precipitate is a natural polymer which can be dried overnight and molded into a variety of shapes. The project team attempted this experiment as well, and was able to produce an excellent result. From this test, the team decided it was best to include a note in the teacher's guide that the instructor should heat the milk and the students should always wear hand protection. Ideally, this experiment would be performed in a ventilated area, as there is a strong odor from the vinegar.

Figure 5: Casein removed from milk

The project team hopes to test the experiments in a classroom setting and observe students as they complete each one. From these observations, further modifications and improvements to the programs can be made.

4.6 Developing Instructional and Background Materials

One of the first decisions necessary when designing the loan box was what form the instructional materials should take. During an interview with Martha Cyr, the group learned that visual instruction in the form of a PowerPoint presentation or video is usually the most effective way to keep students' attention (personal communication, November 14, 2007). The outreach professionals at the London Science Museum confirmed this point, adding that it is also important to be careful to teach to the level of the students and not too far above or below them (personal communication, January 9, 2008). The group chose to use PowerPoint because it would allow the teacher maximum flexibility in choosing exactly which sections he or she wants to use based on the level of the class and the curriculum. A PowerPoint presentation would also be more engaging for the students and the teacher; whereas a video would provide a passive form of instruction and students may not be as motivated to pay attention.

4.6.1 PowerPoint Presentation

The PowerPoint contains three main sections. The first is brief background material on important aspects of material science. Topics such as polymers, copolymers, and mechanical properties are covered and accompanying pictures to illustrate important points. The pictures also help keep the students engaged as wordiness discourages them from paying attention. The next section contains instructions on the class experiments. Students will also be given worksheets with the same instructions. Though doing so may seem redundant, the group decided after speaking with the main liaison for the project, Amy Preece that using both would be best. Each set of instructions has pictures from when the group carried out the experiments, so that students could also see visually what they were supposed to be doing, rather than just reading. Finally, the PowerPoint contains optional extensions which the teacher can use if time allows. This section covers polymers in biomedical applications, an optional hands-on activity, and how polymers relate to smart materials and nanotechnology. The main section of the PowerPoint is geared towards students in the mid-range levels; therefore the extensions provide additional material for more advanced classes.

After speaking with Ms. Preece, the group also realized that it would be a good idea to create another PowerPoint for lower-level classes or those with special needs students. While this presentation still has much of the same information, it is simplified so that those students are not left behind by information that is too complex. Some of the more advanced material and terminology are left out, and more pictures are included to help with understanding of the material.

4.6.2 Teacher's Guide

In addition to the PowerPoint presentation, the project team designed a teacher's guide. It was written in order to give clear instructions on how to implement the outreach program into the curriculum. The guide includes a detailed outline of each experiment and information on how they each work. Teaching notes that state the relation of the experiment and polymers and body protection are also included. Each PowerPoint presentation is supplemented with a guide listing relevant information for each slide. The overall goal of the teacher's guide is to provide the instructor with everything needed to use the program in the classrooms.

Although many of the activities in the outreach program are targeted for Key Stage 3 (KS3), the teacher's guide gives Key Stage 4 (KS4) extensions on GCSE topics such as nanotechnology and smart materials. Each extension includes more information, PowerPoint presentations, suggestions for class discussions, and additional activities.

Most importantly, the guide lists how the program falls under the QCA and other examining boards' standards for GCSE preparation. Each experiment begins with a list of all the standards in both KS3 and KS4 to which it applies. Part of the guide is dedicated to the individual topics incorporated in the National Curriculum.

The project team also developed supplementary materials which can be given out to students. A separate worksheet was designed for each experiment and contains background on the topic, hazard warnings, experimental procedure, and review questions. Once the experiment is completed, students should discuss their conclusions and answer these review questions with their group members and/or class.

Lastly, an evaluation form was formulated and included in the loan box for teachers to fill out with their opinions of the program and suggestions for improvements. These evaluations will be a resource for the Royal Armouries for the development of the program during its pilot testing.

4.7 Interviews

Prior to arriving at the project site, the group conducted several interviews in the US. Individuals at WPI with professional experience in topics related to the project were chosen as interview subjects, such as material science (Professor Demetry), outreach programs (Martha Cyr), and armories (Professor Forgeng). These interviews provided insight and helpful information for getting started on the loan box program. Once in London, the group also conducted an interview with outreach professionals at the London Science Museum. Teachers and other professionals recommended by the staff of the Royal Armouries were contacted with questions via email, and informal interviews were conducted with teachers visiting VisionWorks.

4.7.1 Interviews in the US

The group visited Professor Forgeng, the curator at the Higgins Armory, on November 9, 2007 to discuss outreach and education from an armory's perspective. As curator, Professor Forgeng focuses more on the exhibits and preservation of the artifacts, though he did have some useful information about the goals of museums and how they are run, as well as some general ideas on outreach. Learning how museums/armories work was essential before the group even began the project, given that the sponsoring organization falls into this category. Professor Forgeng recommended extensive research on the topics our loan box would cover so that the information was as accurate and in-depth as possible. He also suggested that the program include a teacher's packet containing information about the museum, pictorial examples of exhibits and artifacts, and if possible, video clips.

On November 14, 2007, the group interviewed Martha Cyr, the director of K-12 Outreach Programs at WPI. The main goal of the interview was to learn how to go about creating outreach programs. Questions included how to structure the program, how long it could be before students lost interest, where to get materials and funding, and how best to make the program financially feasible. Mrs. Cyr strongly recommended combining some lecturing with inquiry-based learning to keep the students interested and allow them to learn by doing. She also suggested keeping any objects or names used in the program gender-neutral in order to make all students feel as though the program applied to them. Similarly, she recommended that the material included be taught "because it matters" to the students in some way and relates to the real world. Finally, as to how to evaluate the program's success, Mrs. Cyr suggested defining an objective at the start of the program, and then basing the evaluation on how well and to what extent the original objective was achieved.

Professor Chrys Demetry teaches material science at WPI and also has experience creating and running material science outreach programs for middle-school students, which is the target age group for the loan box program. The group met with her in the afternoon of November 19, 2007, and began by asking about teaching material science, namely the most important aspects of the subject to focus on and what is comprehensible for the target age group. She suggested topics like structure and its relation to the material's properties, effects of temperature changes on polymers, and differences between materials. The focus of the interview then moved on to outreach programs and techniques Professor Demetry had found worked the best, and how to judge the success of a program. Similar to Mrs. Cyr, one of Professor Demetry's biggest recommendations was to keep the program hands-on and inquiry-based. In her experience, students responded best when they were *doing* something, especially if they could relate it to their daily lives or real-world events. This also means minimizing the amount of lecturing the teacher is doing. Professor Demetry suggested a "five-minute rule" for lecturing, i.e. keep it to five minutes or less. That way, students would not lose interest before the program really got started. This interview yielded many helpful hints into how to structure the program and what to include in it.

4.7.2 London Science Museum

On January 9th 2008, the project team traveled to the London Science Museum to meet with two outreach program officers. The objective of this meeting was to gain more insight into what makes an effective outreach program. The two officers, Zoe Carmichael and Libby Burkeman, have been involved in outreach for a combined ten years. They assured the project team that teachers would have little or no interest in the loan box if it did not have connections to the National Curriculum. Furthermore, they recommended the program be cross-curriculum, covering standards in science and design & technology. The project team also stated their concern about keeping the students interested. Ms. Carmichael said that "It is usually OK to start with a brief lecture, but be sure to ask lots of questions. Then begin experiments or demonstrations to keep students entertained." Ms. Burkeman also added that most of the outreach programs do not go on any longer than 45 minutes. She provided a sample program agenda for the project team, which included 10-15 minutes of introduction, 20-25 minutes of work, and finally a 10-minute debrief discussion. Overall, the 30-minute meeting with the outreach officers was successful and gave the project team the necessary information to begin planning the loan box program agenda.

4.7.3 Email Contacts

After consulting with staff at the Royal Armouries, the group compiled a list of individuals to contact via email to request feedback about the loan box program. Ideally these individuals would have responded with their opinions of the program the group had come up with, and offered suggestions for further improvements and what topics they would like to see covered by the program. However, there was very little response to the emails, and as such the group relied on other methods, such as informal interviews and telephone calls, to obtain this information.

4.7.4 Teachers Visiting VisionWorks

During the team's seven-week period at VisionWorks, several classes came in for lecture programs at the facility. Following these programs the team had the opportunity to stay and talk with several of the teachers. These casual interviews provided a chance to see what the teachers would be looking for in a material science loan box, what types of laboratory tools are in the average Key Stage 3 and 4 science classrooms, and whether or not the teacher would be interested in using the finished program.

Claire, a lab technician from Queenswood School, was interviewed following a VisionWorks program on January 16th. When asked about the conditions of the classroom relative to the experiments and loan box she told the team that on the average, every school, public or private, would have preparation materials needed for this loan box (e.g.. beakers, heating equipment, and PowerPoint presentation abilities). Team members then asked her what she thought about each of the different activities that would potentially be included in the loan box. She was familiar with the slime experiment and said that by the time that a student is in secondary school it is likely he or she has made slime before in class. She was not familiar with the other experiments and was interested in how they actually work, specifically the ‘Makin’ Casein’ experiment. She suggested that if the experiments are tied into the National Curriculum, teachers will be more likely to fit them in to their existing lessons.

4.7.5 London Children’s Hospital

Another informal interview was conducted at London’s Children’s Hospital during a Royal Armouries Outreach Program with Ms. Penelope Strivens. This also gave the team the perspective of an informal education setting. A typical outreach program in a hospital has participants that come and go, depending on their treatments and other time constraints. The team’s loan box activities are flexible enough so that the person running the program can plan it around the availability of patients/students. Team members interviewed two educators from the hospital’s staff. They were very enthusiastic about the fact that the program was being designed for Key Stage 3. They said that the majority of programs are made for primary schools and very few for secondary, and that this loan box would definitely be of interest to them. The team also asked if the hospital would readily have the necessary supplies, but the women said these things would most likely have to be bought before the program or included in the loan box, as they did not have those supplies readily available.

4.8 Phone Calls

4.8.1 Initial Calling

The busy school days and packed curriculum in London schools made it impossible for the project team to be able to arrange a classroom visit to evaluate and test the loan box experiments in the seven week timeframe. Instead, the project team decided on calling local schools to speak with to Key Stage 3 teachers and science department heads in order to find out if they would like to use the outreach program and if he or she would like more information on it. Due to the fact that teachers have very tight class schedules, with usually no more than an hour of free time a day, many of the team’s calls either went straight to a voicemail or they were given the email address of a science teacher or the department head. The team made calls to 82 public and private secondary schools. Of these 82 schools there were voicemails left for seven science department heads, the email address of seven different science departments acquired, and eleven teachers, lab technicians, or department heads talked to. Out of these 25 methods of contact, there were thirteen people interested in receiving more information on the loan box.

4.8.2 Replies to Voicemails

Voicemails were left on seven different science department answering machines. The team realizes that most of these will go unanswered, but figured that it might spark some further interest. The number of the Royal Armouries' VisionWorks department was also taken down several times, but there have not been any replies as of the time of this report.

4.8.3 Replies to Emails

The group obtained email addresses of several science departments and teachers were obtained. These were the best method of indirect contact. Out of the seven email addresses received, two individuals answered asking for more information on the program. The team then sent these two educators a draft of the project's Teacher's Guide to give them more information on the program and so they could make suggestions.

4.8.4 Direct Communication

Between January 29th and February 1st, 2008, the project team talked to eleven educators. Of these educators, all eleven asked to be emailed more information about the box. Many were noticeably excited over the program as well. Alex Hempley, a Chemist from Chiswick High School remarked, "That sounds fantastic. It definitely seems like something that Andy [the science department head] would be interested in. Especially if it connects to the National Curriculum, that sounds fantastic." H. Pithwa from the Mellow Lane school said, "I would like more information on it…It sounds like a program that would be feasible for our school." Christine Kingham, a lab technician from St. Edwards CE said, "Yes! We would definitely use it. If they [teachers] can fit it in [to lessons], they'd use it. It sounds like it is directly relevant with our lessons. We have a whole polymer section…" She also commented that the school science club could potentially use the program as well.

Figure 6, below, shows that direct contact was by far the best means of getting feedback on the program. Every person that the team personally talked to requested more information on the loan box.

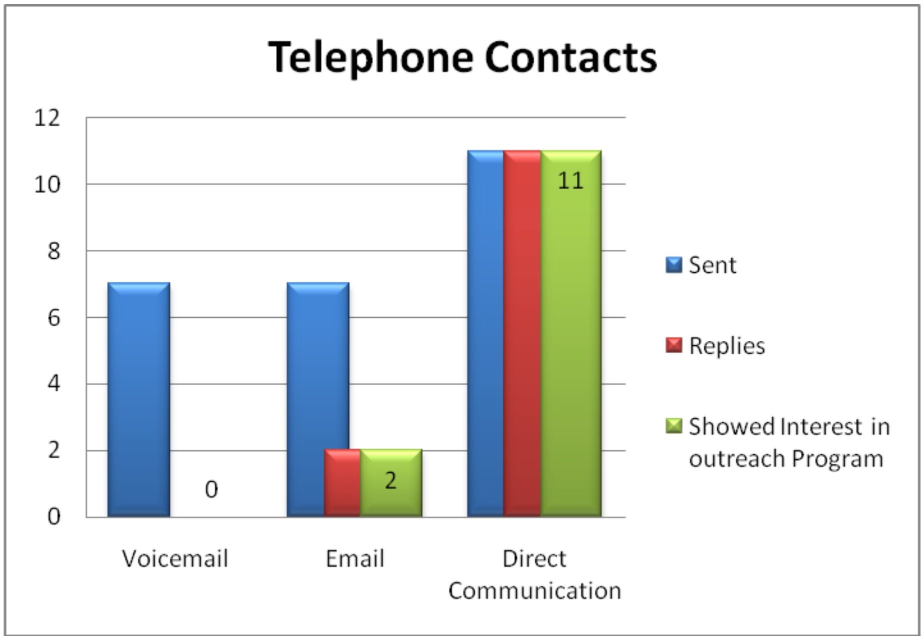

Figure 6: Telephone Contacts

4.9 Costs and Budgeting

The Royal Armouries made it clear that minimizing expenses for the program was a main concern, meaning cost and budgeting were important aspects to consider. Ideally, the Royal Armouries would be able to provide the loan box to schools free of charge. The Armouries wishes to make the loan box all-inclusive and equally available to all schools, regardless of their financial capabilities. When designing the loan box activities and deciding what was to be included, the team had to consider what would be most cost effective and develop a strategy to deliver the program as efficiently as possible.

The activities the team chose require resources that are easily attainable and inexpensive. Most of the resources needed to conduct the experiments can be found at a local supermarket. The only exception is acetone, which can be obtained from a local pharmacy. The team used supermarket Tesco as a basis to estimate prices, because of its wide selection, on-line ordering system, and inexpensive prices.

The hands-on materials to be included in the loan box are a combination of items to be purchased as well as items provided by sponsors Bayer and The London Metropolitan Polymer Centre. Advantages of choosing common everyday materials include clarification of the connection between polymers and the students' lives and the ease with which these materials can be procured. Incorporating materials from sponsors would cost nothing to schools or the Armouries, and would provide many examples of polymers used in the material science industry. While many of the materials donated by sponsors, such as the plastic swatches from the London Metropolitan Polymer Centre, are expendable and can be kept by schools, some of the materials are very expensive to replace and must be sent back to the Armouries.

An important part of making the loan box program all-inclusive and therefore more available to schools was including as much of the required program materials as possible. Teachers would be more likely to adopt the program if it only required them to purchase very few or none of the project materials on their own. The team found when interviewing teachers that they were often pressed for time and money and a program that was self-supporting would be more appealing.

The team had to consider that each loan box sent out to schools would need to be customized to meet the needs of the teacher requesting it. The amount of resources needed for each experiment depends on how many students are in the class and the equipment available at each school. Teachers may also not want to conduct all of the activities, so only resources for the requested parts of the program will be included. Each box will be shipped out with all of the hands-on material, including plastic samples from Bayer and polymer swatch samples from London Metropolitan Polymer Centre as well as laminated photos of the Armouries collections. To ensure that everything returns to the Royal Armouries, a deposit will be made by the school prior to receiving the box. The electronic educational tools including the teachers guide, PowerPoint and worksheets will be on a CD and will also be returned.

The Royal Armouries will purchase all of the non-perishables needed for the experiments. The estimated budget, Appendix F, shows how the costs are broken down. The budget is broken down in to two categories, fixed costs, and variable costs. Fixed costs will be a one-time purchase by the Royal Armouries and includes everything that will be sent back with the box. They are covered by a deposit the school must pay upon requesting the program. The variable costs are what the Royal Armouries will be paying each time the loan box is sent out. The budget shows the estimated variable costs for a class with eight groups of students. The school requesting the program will be required to pay the courier costs needed for transporting the box. Listed in the budget are examples of estimated courier costs to various destinations within Greater London. To provide more flexibility, the option of sending out Royal Armouries Education Officer, Amy Preece, is also included in the budget. This would entail Ms. Preece travelling with the box via taxi and conducting the outreach session in person. The school would pay for the travel costs for Ms. Preece as well as her time for the outreach session.

5. Conclusion

Through research, interviews, and testing, the team has designed what it feels will be a successful a material science outreach program for the Royal Armouries' Bayer Material Science VisionWorks Learning Center at the Tower of London. The following are the team's conclusions on feasibility of the program and suggestions for its implementation.

5.1 Feasibility

5.1.1 Demand for the Loan Box

One of the major aspects of the project was making sure that it was practical for the Royal Armouries. The team specifically looked into costs and demand for such a program when considering if the program was feasible or not. After several interviews, it was obvious that there was significant demand for the program. Many educators and science department heads the group contacted were intrigued by the program and asked for more information on it, adding that it was something that could definitely be used in their school's classrooms. For example, Ms. Janet John from the Dr. Challoners Grammar School told the team that her school has a number of Science Days in the summer term which she could plan around material science in order to incorporate the loan box. All of the teachers with whom the team made direct contact, either initially or after a returned phone call/email response, asked for more information in the loan box. This positive response shows that there will be a demand for the loan box.

5.1.2 Cost

Cost was also a major issue in determining the practicality of the loan box. To minimize the cost of the box to teachers and the additional materials they would be required to purchase, the team decided that most of the materials for the experiments and activities should be included in the box, meaning the Royal Armouries would be responsible for providing these items. After researching the cost of including each item and consulting with Royal Armouries staff, the team concluded that this option was not only feasible but also the most practical. Appendix F shows the proposed budget.

The loan box program was designed to center around everyday polymers and experiments that can be performed with items found in the home. The team felt this would be the most effective way for students to see that polymers affect their daily lives in many ways, thereby increasing their interest in the subject.

5.2 Suggestions

Upon completion of the project, the team has made several recommendations in order to optimize the effectiveness of the Royal Armouries' VisionWorks Outreach experience.

5.2.1 Website

During the interview process a teacher asked the team if there was a website that she could refer to in order for more information. The team feels it would be extremely beneficial for the VisionWorks program to have an interactive website to accompany the outreach program. This website should expand on the material presented in the outreach program so that a student can log on from home and learn more about material science and the Royal Armouries. It should also provide information for teachers looking to use the loan box and include links pages describing the outreach program and contact information for the Royal Armouries.

5.2.2 Science Clubs

The team recommends that the Royal Armouries also market the loan box to science clubs. Many of the teachers with whom the team talked mentioned the possibility of after-school science clubs using the program. Christine Kingham, a lab technician from Queenswood School, mentioned that the science club at her school is generally inactive because teachers need to put time and effort into planning the experiments and presentations for it. As such, demand would be high for a program that includes all the necessary instructions and materials for several experiments. Using the loan box for science clubs will also help to broaden the horizons of these students, who already demonstrate an interest in science, ideally sparking their interest in material science in particular.

5.2.3 Science, Technology, Engineering and Mathematics Network (STEMNET)

In a response to one of the team's emails, an education officer suggested using STEMNET's Education Ambassadors (SEAs) to present the loan box to schools. SEAs are science professionals who volunteer their time free of charge to teach science, engineering, and mathematics programs to children. It would be beneficial for the Royal Armouries to get in contact with STEMNET to discuss the option of having their SEAs present this loan box to school classrooms or science clubs. Bringing a professional with experience in science will enhance the effectiveness of the loan box, as this professional will likely be more knowledgeable than a regular teacher about the topics covered by the box. STEMNET has many connections with educators and would make the task of finding schools that want to use the loan box much easier for the Royal Armouries.

5.2.4 Further Outreach Programs

The heart of the Royal Armouries, as with any museum, is its collection. The existing outreach programs offered by the education department consist of showing and handling replicas and authentic pieces of armor and weaponry. After observing several of these programs the team noticed that the students were especially interested in the handling parts of the sessions. The loan box that the team created was designed specifically to focus on material science and its relation to the history and future of armour and weaponry, but also to include first-hand experience with artifacts. The project team suggests that the Armouries follow up on the loan box program with an armor handling session. This will both work to reinforce and expand upon educational topics covered in the loan box sessions.

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Appendix

Appendix A: Teacher's Guide

Royal Armouries

VisionWorks Material Science Outreach Programme
Teacher's Guide

ROYAL ARMOURIES

Dear Teachers and Educators,

Thank you for your interest in the Material Science Loan Box Outreach Programme. The programme is intended to take two class periods of approximately one hour each. We realize that there are extensive demands on your time, and as such the programme has been designed to be flexible so that you can choose the modules you feel are most relevant to your curriculum. The programme is designed mainly for Key Stage 3, but extensions and further activities have been included for more advanced classes and Key Stage 4.

Many of the materials needed for the experiments are provided for you in the loan box. We ask that you return anything you didn't use and be sure the non-disposable materials remain in good condition. If you have any questions please feel free to contact the Royal Armouries Education Department at **020 3166 6671.** If you enjoyed this programme, the Royal Armouries recommends booking a session at the VisionWorks Material Science Learning Zone at the Tower of London. For more information, please contact Amy Preece at **020 3166 6671** or email her at **amy.preece@armouries.org.uk**.

Thank you and enjoy the programme!
The Royal Armouries Education Team

Note: The experiments included in this guide are best done in groups of 2-5 pupils.

Table of Contents

The Correlation between this Outreach Programme and Key Stage 3 National Curriculum

This outreach programme has been made to directly supplement the Key Stage 3 National Curriculum as well as to expand upon it. The major attainment target that it highlights in science is "Materials and their Properties."

Materials and their properties
The major targets, as shown in the National Curriculum, are bulleted with the relative experiments following:

- A range of materials and their properties.
  - Balloon Kebabs
  - Hands On Demonstration
- The nature of different materials.
  - Balloon Kebabs
  - Hands On Demonstration
  - Secret State
- Ways in which materials can be changed and patterns in these changes
  - Secret State
  - Makin' Casein
- How the properties of materials relate to the nature and organization of the particles they contain.
  - Secret State
  - Makin' Casein

This outreach programme has also been designed with the D&T National Curriculum in mind.

D&T the level descriptions show progression in the three aspects of:

- Developing, planning and communicating ideas.
- Working with tools, equipment, materials and components to make quality products evaluating processes and products.
- These aspects are seen in the 'Protecting the Future' activity in which students hypothesize different uses for modern day plastics and polymers in their lives. Then, in a group, they create a plan, carry out the formation of armour, and evaluate it in front of the class.

Balloon Kebabs

QCA Standards: Unit 8E (atoms and elements)

GCSE Standards:

OCR Science Guide Sections

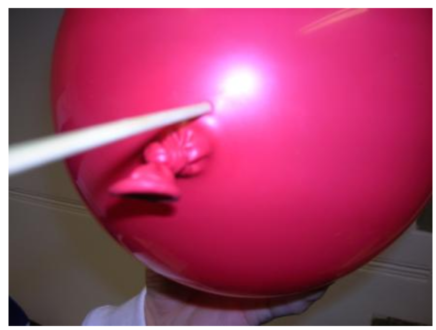
Chemistry – Structure and bonding

QCA (for GCSE engineering)

The properties, characteristics, and features of materials that affect:

- *Ability to be shaped and formed,*
- *Ability to be treated,*
- *Ease of handling and*
- *Availability, form and supply.*

Objective: This experiment is intended to be performed as an introductory demonstration by the instructor. The purpose of the demonstration is to introduce the properties of polymers without immediate lecturing. It will explain that all polymers are made up of chains that can remain strong until they are stretched. Instructors are advised to practice this demonstration before trying it in front of the class. The desired outcome of the demonstrations is that the balloon will not pop and the bag of water will not leak.



Apparatus:

rubber balloon (provided)

cooking oil or other lubricant (provided)

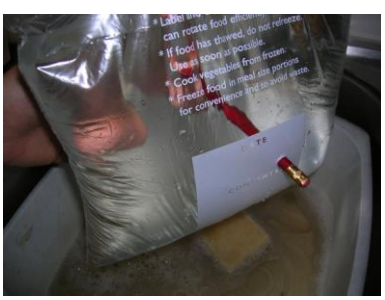
sharpened skewer (provided)

plastic sandwich bag (provided) filled ¾ with water

sharpened pencil

Procedure:

1. Blow up a rubber balloon about half-way. Do not make the balloon taut.
2. Place a little cooking oil on the tip of a sharpened skewer and push it completely through the balloon starting next to where the balloon is tied. Then continue to push it through the balloon and out the darkened area at the top (next to the nipple).
3. Discuss with the class what they think is happening and why. If you chose, poke another skewer into the side of the balloon to show it will instantly pop.
4. Next, fill a re-sealable plastic sandwich bag 3/4 full with water. Push a sharpened pencil completely through the centre of the bag.



5. Once again ask, "Why do you think the bag does not leak?" "Is there a similarity between this and what happened to the balloon?"

Ask them to discuss the similar properties of the balloon and the plastic bag. See if they can think of any other substances that have these properties. Have them hypothesize what they think is happening in both instances.

Teaching notes:
Why did this happen? All polymers, such as balloons, are made up of many chains, called polymer chains that are so small they are invisible to the naked eye. On the sides of the balloon, these polymer chains are stretched to their limit. At the neck of the balloon the polymers are much less stretched, so when pierced with a knitting needle, there is enough room to allow the needle in between the chains without breaking them. Following this activity, we recommend using the PowerPoint slides included to discuss the molecular makeup of a polymer.

Polymer Hands-On Presentation (Key Stage 3)

We have included in the loan box several examples of common polymers that a person typically uses every day. There are also other examples that you might have in the classroom as well. These have been included so that the pupils can observe different types of polymers and have first-hand experience with them. We recommend using the PowerPoint presentation included. Each slide will introduce a polymer and the loan box includes examples of each to pass around for the students to see.

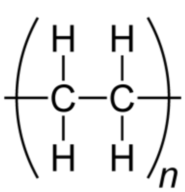
QCA Science Standards:	Unit 8E (atoms and elements) Unit 7K (forces and effects)
QCA D&T Standards:	Unit 08aii (exploring materials: resistant materials)

Objective: To show students the variety of plastics/polymers and how they can be used. This programme shows different properties and applications of polymers. This programme is also intended to spark the pupils' interest in polymers and to have them start thinking about how they affect our lives on a daily basis.

Teaching notes:
-Use the PowerPoint provided and follow the guide below to show how everyday plastics have a wide variety of uses.
-Discuss material concepts including ductility and malleability. Have students use the samples provided to distinguish what properties fit with each sample.

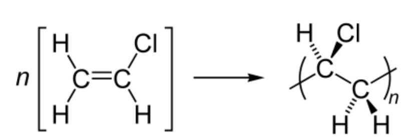
<u>Guide to Hands-On Polymer PowerPoint:</u>

Horn – Supplied in this kit: horn samples. Horn is a natural polymer made out of keratin (a protein). Horn is a thermo-plastic which means it has the ability to be melted and moulded into different shapes. It was used to make items such as knives, spoons, combs and spectacle frames.

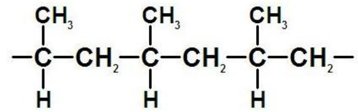


poly(1-methylethylene) (Polyethylene) – Supplied in this kit: Sandwich bag and Polyethylene swatch. Other suggested materials are: Cling wrap, Liquid containers, and fizzy drink bottles. Low Density Polyethylene can be seen in the sandwich bag. It is transparent and flexible due to the fairly loose and irregular packing of polymer chains. The high density form of polyethylene is slightly opaque and much stronger. Freezer bags typically have a higher density form of polyethylene than sandwich bags.

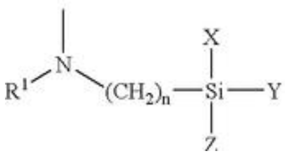
Polychloroethylene (Polyvinyl Chloride) – Supplied in this kit: PVC drain pipe and two PVC swatches. Polychloroethylene is also commonly referred to as Polyvinyl Chloride or PVC. Its biggest application is tubing and vinyl siding on houses but it can also be



used in clothing, flooring and to make garden hoses. It is an extremely cheap and highly durable polymer.

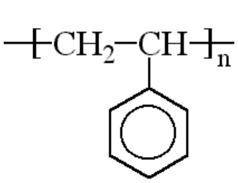


Polypropene (Polypropylene) – Supplied in this kit: Rope and two Polypropene swatches. Other suggested materials are: Prescription Bottles. Polypropylene is stain resistant and is often used in clothing and carpets to make them stain resistant. It is highly heat-resistant and is very resistant to fatigue so it is typically used as the top for containers. For instance, all Tic-Tac containers tops are made of polypropylene.



Ethyl Carbamate (Polyurethane) – Supplied in this kit: Spandex and Polyurethane Swatch (Lycra is the trade name for Polyurethane in its fiber form). Polyurethane is commonly used as foamed insulation. It is produced in both a low-density form (like the foam insulation) and a high-density form (like Spandex)

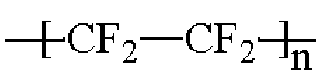
Vinyl Benzene (Polystyrene) – Supplied in this kit: Foam Cup and swatches of General Purpose Polystyrene and High-Impact Polystyrene. Polystyrene is the same as polyurethane in the way that it comes in



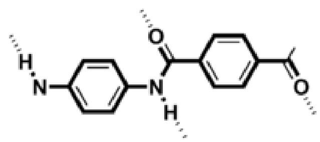
either a hard or foamed form. An example of the foamed form is included in this kit. The hard form is used to make food and drink containers. If you are looking for an example of the hard form for your presentation, anything that has the recycle code #6 is made of polystyrene.

Poly(hexanamide (Nylon) – Supplied in this kit: Toothbrush and swatches of Nylon 6 and Nylon 11. Nylon is a polymer that makes an excellent fibre, which is the most common use of it. It is commonly found in clothing (particularly stockings). Its first use was as toothbrush bristles. It was particularly used during World War II to replace silk when it became scarce. There are many different types of Nylon which are all produced for different properties and can be found in everything from guitar strings to camping tents.

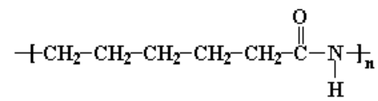
Polytetrafluoroethylene (Teflon®) – Supplied in this kit: non-stick cooking spoon. Teflon® is the trade name for three different fluoropolymers (polymers containing fluoride either

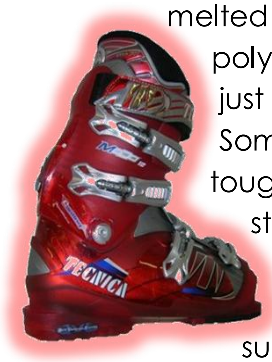


in place or in a combination with hydrogen). Teflon® has the lowest coefficient of friction known to man (either 0.1 or less). This, along with the fact that it is resistant to high temperatures, makes it ideal for many applications. The most common is non-stick pans. It is also used often in industry gears and bearings. Many earrings are also coated with Teflon® and the O_2 dome in London is primarily made of Teflon® as well.



Poly(para-phenylenediamine and terephthaloyl chloride) (Kevlar®) – Supplied in this kit: Swatch of Kevlar® fibre. Kevlar® is one of the strongest man-made materials. It is strung into a fibre and has a number of different uses including: bike tires, racing sails and body armour. The fibre has millions of molecules in a plane while only one molecule in thickness. Specific to the Royal Armouries, Kevlar® is used in all riot vests. A typical riot vest has 10-30 layers of Kevlar® fabric. The material is about 5 times as strong as steel yet still fairly flexible and maybe even strong enough to stop a speeding bullet!





Polycarbonate (Makrolon®) – Supplied in this kit: Makrolon® pieces and a swatch of Polycarbonate. Makrolon® is a thermoplastic, meaning that it can be melted down and moulded into different shapes. It is the trade name for a polycarbonate manufactured by Bayer Material Science. Recently, it has just been announced that it is going to be used to make LCD screens. Some of its properties include: excellent transparency, high strength and toughness, impact and fracture resistance, very good heat and weather stability. It is seen in many 'shatter proof' objects and is also used to make: CDs, DVDs, eyewear and automotive headlamps. Specific to the Royal Armouries, Makrolon® is used in many protective materials, such as plastic pads, and guards.

Guide to Hands-on Polymer PowerPoint: This programme is designed to let the students be able to relate these polymers to materials they use in their everyday lives. This presentation has been broken into four sections. The first polymer, horn, is a man-made plastic. We have included horn in this presentation to inform students that not all plastics are man-made. Students will be tested on the next three polymers in the GCSE's (polyethene, polypropene and polyvinyl chloride). The next four polymers are used in products that they use every day (polyurethane, polystyrene, Nylon and Teflon®). This is to spark their interest and keep them thinking about polymers long after this presentation is finished. The last two polymers (Kevlar® and Makrolon®) are specific to protection and the Royal Armouries. This is cutting edge technology that should excite the students.

__**Suggested Questions during the presentation**__

1. What are the properties for (each polymer)?

2. What are some uses for (each polymer) that you can think of? Consider its properties.

3. How many of you have used a polymer at some point today?

4. Do you know of any polymers not included in this presentation?

5. How many bonds do you see in (each polymer)?

6. What does the double line between two carbons mean?

Recycling Codes for Everyday Polymers:

(These codes can be used as a guide for finding more polymers to use for the hands-on demonstration)

1	PET	Polyethylene terephthalate - Fizzy drink bottles and oven-ready meal trays.
2	HDPE	High-density polyethylene - Bottles for milk and washing-up liquids.
3	PVC	Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.
4	LDPE	Low density polyethylene - Carrier bags and bin liners.
5	PP	Polypropylene - Margarine tubs, microwaveable meal trays.
6	PS	Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.
7	OTHER	Any other plastics that do not fall into any of the above categories. - An example is melamine, which is often used in plastic plates and cups.

Polymer Hands-On Demonstration (Key Stage 4 Extension)

The PowerPoint presentation for Key Stage 3 and 4 has been made so that teachers may go as in-depth with the polymers as they feel appropriate.

GCSE Standards:
OCR Science Guide Sections:
- *Chemistry – Structure and bonding*

AQA
Unit Chemistry 1:
- *11.1 – How do rocks provide building materials?*
- *11.3 – How do we get fuels from crude oil?*
- *11.4 – How are polymers made from oil?*

Unit Chemistry 2:
- *12.1 – How do sub-atomic particles help us to understand the structure of substances?*
- *12.2 – How do structures influence the properties and uses of substances?*
- *12.3 – How much can we make and how much do we need?*
- *12.5 – Do Chemical Reactions always release energy?*

QCA (for GCSE engineering)
Engineering materials and the properties in the following groups:
- *Polymers.*
- *Composites that combine the properties of different materials.*

The properties, characteristics and features of materials that affect:
- *Ability to be shaped and formed.*
- *Ability to be treated.*
- *Availability, form and supply.*

Edexcel
Module 4: Chemistry in Action
Topics:
- *Crude Oil*
- *Plastics*
- *Types of Chemical Reactions*

<u>Suggested Questions during the presentation</u>
We recommend that these questions be asked while a polymer's slide is on or during discussion of the polymer.

1. What type of classification can you place on polyethylene and polypropylene?
Answer: Hydrocarbons

2. Draw the monomer for (each polymer).

3. What are some other uses for these polymers?
Answer: This is really open-ended, let the students use their imaginations and consider the properties of specific high-density and low-density polymers.

4. Do you know of any other polymers you use every day?
Answer: Some car interiors are made with polypropylene. The polymer Teflon® is used on kitchen appliances because of its non-stick characteristic. Polyurethane foam is typically used as the insulation in homes. We have also included a recycling code chart so that you can find other common polymers. This chart can also be incorporated into your discussion

Key Stage 4 Extension: Biomedical Engineering

Another PowerPoint presentation on the recent advancements in biomedical engineering, specifically on polymers, is provided on our CD. A guide is included below for each of the slides to help with instruction on them.

Guide to Biomedical Engineering PowerPoint:

This extension is designed to give students further insight into the vast array of fields in which polymers have an important role. People are living longer creating a need for new devices to replace worn-down or failing body systems. Advances in drug delivery systems have allowed for more precise, faster treatment of a wide variety of ailments. Thanks to polymers, what may once have been a death sentence is now a curable condition.

Slide 1 – Natural & Synthetic Polymers

Polymers are not only manufactured, they are also produced within the body. Proteins, sugars (polysaccharides), and poly-amino acids are all polymers which are naturally produced within the body. There is an extensive range of synthetic polymers which can be mass-produced in large quantities. Both natural and synthetic polymers have an extensive range of possible biomedical applications, ranging from prosthetics and drug delivery systems to stents and replacement heart valves.

Slide 2 – Natural & Synthetic Polymers (table)

There are many advantages which natural polymers have over synthetic polymers, and vice versa. Since natural polymers are produced within the body, they are already biocompatible, whereas synthetic polymers must be carefully engineered so as not to cause an immune response. Natural polymers also degrade naturally and are more easily able to interact with other substances in the body. However, they are difficult to manufacture in large quantities. In addition, natural polymers are often very difficult to modify to fit the specific need of the recipient. Synthetic polymers can be produced in large quantities and modified to have specific qualities and perform specific functions. The degradation of such polymers may not be ideal, requiring either frequent replacement or removal of the device.

Slide 3 – Polymers in Drug Delivery

Polymer drug delivery systems are a promising advance in biomedicine. Polymers can be used to protect drugs from harmful biological environments until they are ready to be released. They can also provide a support structure onto which the drug can be attached or embedded, and then implanted in the body. This allows for more precise delivery of the drug as it can be placed exactly where it is needed. Higher concentrations may also be implanted initially and then measured amounts of the drug released over time, lessening the need for repeated treatments and painful injections.

Slides 4 & 5 – Polymers in Drug Delivery: Degradation

The way in which the polymer degrades determines the speed and means by which the drug is delivered. Bulk degradation occurs when a polymer is hydrophilic (attracted to water). The water is allowed to enter the polymer and begins breaking it down from the inside, eventually causing the polymer to collapse and release the drug all at the same time. This is called burst release. Surface erosion occurs in hydrophobic polymers, which are those that repel or are repelled by water. The water slowly wears away the outer surface of the polymer, breaking it down and releasing the drug at a slower, more controlled rate.

Slide 6 – Polymers and Stents
Stents are medical devices used to hold open blood vessels either in danger of collapse or becoming completely blocked by plaque and other buildup. In the past, stents were commonly made of metal, but have recently begun to be made out of polymers. Polymers can also be applied as a coating for the stents, and drugs embedded in the polymer for delivery through the bloodstream. Though they are promising, there are a few common problems with polymer stents, including inflammation of the vessel and clotting. Research is being done to eliminate these side effects.

Slide 7 – Heart Valves
Extensive work has been done in developing replacement heart valves for patients whose valves are failing or did not form correctly. There are several types of valves, depending on which of the many in the heart needs to be replaced. Some examples are shown in the pictures, such as caged-ball valves, tilting disk valves, and manufactured copies of biological valves. Polymers play a major role in making the valves more biocompatible, enabling them to remain in the body for a longer period of time and require fewer replacement procedures than earlier valves.

Makin' Casein (KS3 Experiment)

QCA Science Standards: Unit 8F (compounds and mixtures)
Unit 9H (using chemistry)

Apparatus:
125cm³ of whole milk
40cm³ of white vinegar (provided)
beaker
food colouring (optional)
filter funnel
mixing spoon
Bunsen burner

Hazards: Use proper hand and eye protection during this experiment
Vinegar and casein can be harmful if swallowed

Objective: The main objective of this experiment, which should be done in small lab groups, is to show that polymers can also be produced naturally. Most students are under the assumption that polymers are manmade, but using only milk and vinegar they will realize this is not true. Natural plastics such as horn have been used before manmade plastic was invented. In this experiment students will precipitate casein from milk and vinegar and be able to mold into different shapes.

Procedure:
1. Measure the milk and place in the beaker. Slowly warm the milk, but do not boil.
2. Add several drops of food colouring to the milk so the object you form will be coloured. Remove the beaker from the heat. Slowly add the vinegar into the milk.
3. Use the filter paper to separate the solid that has formed from the liquid in the pan. This solid is a plastic.
4. After the liquid has drained through the filter, pour a little water through the strainer to rinse the plastic.
5. Form the plastic into a ball and set it on a paper towel for a few minutes to remove some of the excess moisture.
6. You should then be able to form the plastic into the object of your choice.
7. When you have finished shaping your object, set it aside for a week to dry. The object will probably shrink a little as it dries out.

Conclusion:
Why did this happen?
Combining an acid (vinegar) with heat precipitates casein (a protein) from the milk. Casein is not soluble in an acid environment; therefore, when vinegar is added it will appear in the form of globular plastic-like lumps. Casein behaves like the

plastics that we see in so many objects around us, such as computer keyboards or phones, because it has a similar molecular form. As explained in the "Balloon Kebabs" activity, the plastics in these everyday objects are based on long-chain molecules called polymers. These are of high molecular weight and get their strength from billions of interwoven "criss-crossing" molecules tangled together.

The History of Casein

Casein was first exhibited as a plastic in 1900 under the trade name *Galalith*. Making commercial casein was difficult until 1914 when the 'dry process' of making casein plastic was introduced. Casein is very easy to colour and dye, which made it very popular in the fashion industry, especially for buttons. It was also widely used to make fountain pens. By the 1980's the production of casein was nearly nonexistent due to the fact that production of casein was tedious and the increasing number of man-made materials.

Makin' Casein (KS4 Experiment)

GCSE Standards:

OCR

- *Chemistry – Structure and Bonding*
- *The Unique Properties of Water – Electro negativity, exchange of electrons*

QCA (for GCSE engineering)

- *QCA Engineering Materials – Polymers, Composites that combine the properties of different materials*
- *The properties, characteristics, and features of materials that affect:*
    - *ability to be shaped and formed*
    - *ability to be treated*
    - *ease of handling*
    - *availability, form and supply*

AQA

- *12.5 – Do Chemical Reactions always release energy?*
- *13.2 What are strong and weak acids and alkalis? How can we find the amounts of acids and alkalis in solutions?*
- *13.4 How much energy is involved in chemical reactions?*

EDEXCEL

Module 4: Chemistry in Action

Topics:

- *Enzymes*

Apparatus:

125 cm^3 of whole milk
25 cm^3 of white vinegar (provided)
5 cm^3 of Sodium hydrogen carbonate (provided)
Beaker (250 cm3)
stirring rod
Filter funnel and filter paper
Paper towel
Conical flask (250 cm3)
Bunsen burner
tripod and gauze

Hazards: Wear proper hand and eye protection during this experiment
Vinegar can be harmful if swallowed

Objective: The main objective of this experiment, which should be done in small lab groups, is to show that polymers can also be produced naturally. Most students are under the assumption that polymers are manmade, but using only milk and vinegar they will realize this is not true by creating a polymer that they can mould into different shapes. The KS4 experiment is designed to be more laboratory-based and involves more GCSE topics as well as another chemical reaction.

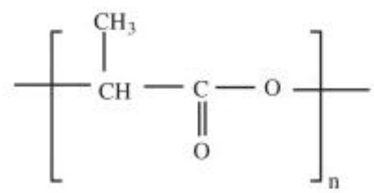
Procedure:

1. Measure out about 125 cm^3 of whole milk into the 250 cm^3 beaker.
2. Add about 25 cm^3 of vinegar and place the beaker on the tripod under the heat.
3. Gently heat the beaker, stirring constantly, until small lumps begin to form.
4. Once the lumps appear, remove the beaker from the heat, and continue to stirring until the lumps stop forming
5. Allow the substance to settle, and then remove some of the liquid. Filter off the remainder of the liquid into the conical flask using the funnel and filter paper.
6. Use the paper towel to remove excess liquid from the substance.

7. Transfer the dried out substance to the empty beaker, add about 15 cm^3 of water and stir.
8. Add about 3 cm^3 of sodium hydrogen carbonate. Once bubbles of gas appear, add the remaining sodium hydrogen carbonate until it stops bubbling.
9. Stir the solid. What has been created? Hypothesize how this happened?

Teaching notes:
Casein is the predominant protein found in sour milk products such as yogurt and some cottage cheeses. In milk it exists in the form of a soluble calcium salt. Milk contains lactic acid. When mixed with the vinegar, the lactic acid in the milk is oxidized and forms polylactic acid, a monomer.

The casein protein in milk is curdled by lactic acid. Although it can be fermented from lactose (milk sugar), most commercially used lactic acid is derived by using bacteria such as *Bacillus acidilacti*, *Lactobacillus delbueckii* or *Lactobacillus bulgaricus* to ferment carbohydrates from nondairy sources such as cornstarch, potatoes and molasses.



Poly(lactide)

Lactic acid may be found in various processed foods, usually either as a pH adjusting ingredient, or as a preservative. It may also be used as a fermentation booster in rye and sourdough breads.

Discussion:
Suggested Questions:

1. What do you think is the purpose of the vinegar in this experiment?
Answer: To convert the casein into an insoluble form.

2. Why is sodium hydrogen carbonate added?
Answer: To remove any excess acid.

3. What is the gas given off when the sodium hydrogen carbonate is being added?
Answer: Carbon dioxide - acids react with carbonates to form this gas.

4. Where can you find casein?
Answer: In addition to being consumed in milk, casein was used to manufacture adhesives, binders, protective coatings, fabrics, food additives, and many other products.

Secret State

**Be sure students handle the corn flour mixture over the laboratory sink. Although the experiment can be messy, students will really enjoy it.

QCA Science Standards: Unit 7F (simple chemical reactions)
Unit 8F (compounds and mixtures)
Unit 9H (using chemistry)

Apparatus:
125g corn flour (provided)
100cm³ water
metal mixing bowl (provided)
spoon

Objective: Showing how polymers are changing the world we live in is an important theme to this programme. In this experiment, a corn flour and water mixture is used to show how a shear thickening fluid works. Discussions following this activity will help pupils learn how STFs are useful and why they are important to our future.

Procedure:

1. Mix the corn flour with the water in the metal mixing bowl.
2. Stir the mixture until it becomes difficult to move the spoon. Tip the bowl and then stir the mixture again vigorously.
3. Drip your finger slowly in the liquid until it touches the bottom of the bowl. Then pull it out in a hurry and it will solidify.
4. Quickly drag your fingers through the liquid and lift out a putty-like ball that you can work in your hands. Be sure to keep your hands over the bowl and open your fingers.
5. Have the groups discuss what has happened.

Teaching notes:
How did this happen?
The corn flour mixture created is known as a dilatant material or a shear-thickening fluid. The viscosity (ability to flow) in dilatant materials increases as the force, or shear, on them increases. Therefore, as pressure is applied to the substance, it will become more resistant to deformations.

Research into shear-thickening fluids (STF), such as the substance created in this experiment, has led to the development of 'smart materials', ones that respond to changes in their surrounding environment. For example, military researchers are attempting to treat fabrics with STFs so that when a bullet strikes an STF-treated uniform, it will become rigid at the point of impact and the bullet would fail to penetrate. Under normal conditions, however, the fabric would be as flexible as normal clothing.

Secret State (KS4 Extension)

GCSE Standards:

OCR

- *The Unique Properties of Water – Breaking and Forming bonds through condensation and evaporation.*

QCA (for GCSE engineering)

- *Engineering Materials – Polymers, Composites that combine the properties of different materials.*
- *The properties, characteristics, and features of materials that affect:*
    - *Ability to be shaped and formed,*
    - *Ability to be treated,*
    - *Ease of handling, and*
    - *Availability, form and supply.*
- *Engineering processes:*
    - *Shaping and manipulation and*
    - *Heat and chemical treatment.*
- *New technology used in and by the engineering industries.*
    - *Modern and 'smart' materials and components.*
- *The Impact of modern technologies:*
    - *Advantages and Disadvantages that the use of modern technology has brought to society.*
- *Engineered products:*
    - *Investigate a variety of engineered products that use modern technology.*

AQA

- *11.4 – How are polymers made from oil?*
- *12.1 – How do sub-atomic particles help us to understand the structure of substances?*
- *12.2 – How do structures influence the properties and uses of substances?*
- *12.5 – Do Chemical Reactions always release energy?*
- *13.2 – What are strong and weak acids and alkalis? How can we find the amounts of acids and alkalis in solutions?*
- *13.4 – How much energy is involved in chemical reactions?*

Teaching notes:

For this Key Stage 4 extension, the Key Stage 3 experiment will be used followed by a discussion on Shear Thickening Fluids and how they are used today.

Corn flour particles are tight, closely bonded molecules. When energy from the water is added, it reaches the corn flour molecules' specific heat capacity. This causes the covalent bonds within the molecule to break, producing a larger, but loosely formed molecule.

When you stir the solution, or when any shear stress is applied, bonds are reformed between the molecules, making a long polymer-like chain. Corn flour acts as a Shear Thickening Fluid (STF). A STF is a fluid that acts like a solid when stress is applied. Recently, there has been a lot of research into making 'liquid armour' from STFs by using different forms of polymers, such as Kevlar®.

There are also Shear-thinning Fluids, such as blood, nail polish, toothpaste and ballpoint pen ink, which get more fluid when force is applied.

Discussion: Where might shear thickening fluids be useful today?

Arm/ Leg casts and braces, mouth guards, helmets, kneepads, shin-guards.

Protecting the Future

QCA Science Standards: Unit 7K (forces and bonding)

QCA D&T Standards: Unit 07aii (understanding materials: resistant materials)
Unit 08aii (exploring materials: resistant materials)
Unit 08bii (designing for clients: resistant materials)

If feasible, the Royal Armouries suggest booking an outreach session where classes could have a hands-on experience with pieces from our armour collection.

Introduction:
Begin the activity with a "show and tell" of several included photos of armour, both modern and historic. Have students discuss what are the pros and cons of a bulky metal armour as well as modern protection such as a riot vest. If the class has not already attempted the corn flour experiment, it would be best to review what a smart material is. After a brief introduction on polymer tensile strength (in PowerPoint provided) and atomic bonding, have class divide into groups of 4-5 students. Using the everyday polymers listed below, have the students design their own "futuristic" armour that will demonstrate protection as well as comfort. (Example: a strong chest plate, but flexible and lighter elbow areas.)

Everyday polymers:
*supplied by the Royal Armouries

*rubbish/plastic bags
fizzy drink bottles
*milk cartons
duct tape
*plastic gloves
cardboard
*cling film
tights/stockings
Polystyrene plates
egg cartons
plastic cups
plastic hair clips

Activity:
Give the students 25-30 minutes to design their armour, most likely just a chest plate or helmet. Once everyone is finished, let the groups try on each other's armour and compare safety and comfort. Also, it could be possible to lay the armour flat on the ground and drop light masses on them to test their strength.

Scenario for Students:
Your class has been hired by a company which specializes in 'smart material' body protection. Each team is to design a prototype of a 'futuristic' type of protection using the materials supplied. The protection can be designed for any part of the body your team decides upon. Remember to consider comfort and flexibility as well as safety and durability in your design. For example, if your group is designing protection for the legs, be sure they are flexible at the knees and will allow the user to still run comfortably. Be creative in your design. Remember, it's only a prototype so anything is possible.

Debrief:
Use the end of this activity for students to present their designs. Also, leave time to discuss the material concepts that relate to this activity. It is important to talk about material bonding and how tightly packed bonds can be stronger but not as flexible. Also, talking about tensile strength (amount of stress a material can take before fracturing) will also be an important concept to cover. Finally, be sure to compare the student-made armour with the modern armour photos provided. Show examples such as Kevlar® and explain how strong, comfortable and useful it is. Close with questions and discussion.

Suggested questions:
1. What material properties or characteristics did you consider when creating your armour?
2. What are the advantages and disadvantages to using (select a material) in your design?
3. How important is comfort when designing armour?
4. How does atomic bonding affect the strength of different polymers?

Protecting the Future KS4 Extension:
Smart Materials and Nanotechnology

GCSE Standards:
QCA (for GCSE engineering)

- *Engineering processes:*
    - *Shaping and manipulation*
    - *Heat and chemical treatment*
- *New technology used in and by the engineering industries*
    - *Modern and 'smart' materials and components*
- *The Impact of modern technologies*
    - *When engineering a product*
    - *On engineered products*
    - *On engineering industries*
    - *On stages in engineering a product*
    - *Advantages and Disadvantages that the use of modern technology has brought to society*
- *Engineered products:*
    - *Investigate a variety of engineered products that use modern technology*
    - *Investigate the impact of modern technology on the design and production of a range of engineered products.*

AQA

- *11.1 – How do rocks provide building materials?*
- *11.3 – How do we get fuels from crude oil?*
- *11.4 – How are polymers made from oil?*
- *12.1 – How do sub-atomic particles help us to understand the structure of substances?*
- *12.2 – How do structures influence the properties and uses of substances*

Note: For this Key Stage 4 extension, the Key Stage 3 activity will be used followed by a discussion on Polymer Nanotechnology and Smart Materials.

Teaching notes:
Polymer Nanotechnology

- Polymer nanoparticles have been manufactured for decades to serve a variety of purposes such as in high performance materials including high impact resistant polymers and specialty coatings
- Nanotechnology refers to particles that can vary in dimension between 1-100nm that means 1 nm is 1/100,000,000 of a meter!
- Synthetic 'nano' materials have been around for a long time; before they were even referred to as their modern title of 'nano' material
- Currently a primary focus of science and engineering has been on using nanoscience to develop these future materials
- The application of nanomaterials serves a variety of purposes in biomedical, structural materials, body armour and in 'smart' materials.

Body Armour

- Currently nanomaterials are being used to reinforce body armour making it lighter, more flexible, stronger and effective than ever before.

- This is being done by using a polymer epoxy composed of spherical nanoparticles of silicon dioxide, titanium dioxide or carbon nanotubes that can be woven in to fabrics.
- These extra strong materials boast strength that rivals steel, while being flexible and incredibly light.

Smart Materials

- Smart materials can be defined as materials that possess one or more properties that can be significantly altered and controlled by external forces such as stress, temperature, moisture, pH, electric or magnetic fields.
- Examples of these are shape memory alloys which are thermo-responsive polymers; meaning deformation can be induced and reverted in response to temperature.

<u>Guide to Nanotechnology PowerPoint:</u>

Slide 1 – What is Nanotechnology?

Nanotechnology first became popular in the 1980s as a way to build tiny machines (molecule-sized) such as robot components and small computers. Over the last 20-25 years, the meaning of the term has changed with innovations in technology. The term “nanotechnology” is now generally taken to mean “understanding and controlling matter at dimensions of roughly one to one hundred nanometers.”[1] One nanometer is one billionth of a meter. For the sake of comparison, a sheet of paper is 100,000 nanometers thick. Nanotechnology is a discipline which combines science, engineering, and technology to allow the manipulation of a material’s physical, chemical, and biological properties.

Slide 2 – Applications of Nanotechnology

While its full range of applications is still being explored, nanotechnology is being applied in many industries today. It is used in electronics, optics, biological and pharmaceutical applications (which will be explained shortly), cosmetics, energy, and materials, just to name a few. Nanoparticles can be combined with other materials to improve functionality and to modify their properties so that they exhibit certain desired characteristics.

Slide 3 – Polymers in Nanotechnology

Polymers are commonly used in the manufacture of nanoparticles because of their wide range of properties and the ease with which they can be modified and produced.

Slide 4 – Nanomaterials & Body Armour

A major area of nanotechnology research is focused on body armour and protection. Polymer epoxy nanoparticles (made up of silicon dioxide, titanium dioxide, or carbon nanotubes) can be woven into fabrics to reinforce the armour and make it stronger and more effective at protecting the wearer than ever before. These reinforced materials rival the strength of steel while maintaining flexibility and a low weight.

Slide 5 – Smart Materials

Smart materials are materials which have one or more properties that can be altered by external stimuli such as temperature changes, moisture, changes in pH, and the application of an electrical current. The concept of electrostatic flocking, where static electricity causes fibres to align a certain way, was used for Batman's cape in the film *Batman Begins*. This example shows the degree to which smart materials are able to change based on the stimuli.

Slide 6 – Nanotechnology in Biomedicine

One of the biggest applications of nanotechnology currently being researched is biomedicine. Smart materials can be used to manufacture drug-containing nanoparticles "programmed" to release the drug only at certain times, i.e. when the concentration of a certain chemical in the body drops below a threshold level. This concept can also be applied to chemotherapy drugs, housed in nanoparticles which target tumors and release the drug directly on the tumor. Finally, nanoparticle coatings can be applied to the surface of many different types of implants to aid in the body's acceptance of the implant while minimizing the chance of complete implant rejection.

Discussion: How are nanotechnologies and smart materials changing our world?

’Melting’ Polystyrene

Note: This experiment is designed for Key Stage 4 or A-level groups

GSCE Standards:

AQA

- Chemistry Section 1
  - *11.1 – How do rocks provide building materials?*
- Chemistry Section 2
  - *12.1 – How do sub-atomic particles help us to understand the structure of substances?*
  - *12.2 – How do structures influence the properties and uses of substances?*

QCA (for GCSE engineering)

- *The properties, characteristics and features of materials that affect:*
  - *Ability to be shaped and formed*
  - *Ability to be treated*
- *Engineering processes:*
  - *Shaping and manipulation*
  - *Heat and chemical treatment*

OCR

GCSE Science Guide Sections:

- *Chemical and Material Behaviour*
- *Structure and Bonding*

Edexcel

Module 4: Chemistry in Action
Topics:

- *Types of Chemical Reactions*

Apparatus: 2 large beakers or containers, 20cm^3 of acetone (provided on request), Polystyrene cups or Polystyrene packing peanuts (provided) , a pipette

Objective: This experiment shows two different forms of polystyrene and their properties. Foamed polystyrene (in the form of a cup or packing material) is the low-density version of the polymer. Due to the fact that polystyrene is soluble in acetone, the air in the foamed low-density version escapes. The hard matter remaining is high-density polystyrene. These two different forms show students that polymers can have the same chemical makeup, but very different properties.

Hazards: Use proper hand and eye protection during this experiment.

WARNING: Acetone is an extremely flammable liquid and is harmful if swallowed, inhaled, or contacted with skin. Use with caution in a well ventilated area.

Procedure:

1. Place two large glass beakers side-by-side. Pour water into the first beaker until it's about half full and leave the second one empty.
2. Place a Polystyrene cup into the beaker that contains the water and observe what happens. The cup simply floats and is not affected by the water.
3. Place a Polystyrene cup into the empty beaker and using a pipette, take a small amount of acetone place several drops on the Polystyrene and observe what happens. The Polystyrene slowly breaks down until it appears as a glob of 'goo.'
4. The 'goo' that results from the dissolving Polystyrene is still the same polymer as the Polystyrene cup in a different state.

Teaching notes:

Polymers are made up of long chains of monomers. These long chain polymers are held together loosely by non-polar bond interactions between chains. Because this polymer is made as foam, there is a lot of air space in between these groups of polymers. The acetone is able to get in between these groups and allow the air to escape leaving you left with a much denser polymer. This occurs because acetone and polystyrene both share the same properties and are both non-polar meaning they have no charge. This leads the principle of 'like dissolves like;' this also explains why the polystyrene cup does not dissolve in water. Water is polar and therefore the polystyrene will not interact with it.

Sample Agenda for Key Stage 3 (2 class periods)

Day 1:
Balloon Kebabs (5-10 minutes)
Brief PowerPoint lecture on molecular structure of polymers (5-10 minutes)
Everyday Polymer Hands-on Demonstration (10-15 minutes)
Makin' Casein or Secret State (15-20 minutes)
Debrief (5-10 minutes)

Day 2:
Review of previous class (5 minutes)
Photograph presentation of modern day protection and historic armour (5 minutes)
Protecting the Future activity (30 minutes)
Armour design presentations (10 minutes)

Sample Agenda for Key Stage 4 (2 class periods)

Day 1:
Balloon Kebabs with KS4 extension (5-10 minutes)
PowerPoint presentation and hands-on polymer demonstration (10-15 minutes)
Makin' Casein (10-15 minutes)
'Melting' Polystyrene (5-10 minutes)
Debrief (5-10 minutes)

Day 2:
Review of previous class (5 minutes)
Photograph presentation of modern day protection and historic armour (5 minutes)
Protecting the Future activity with KS 4 extension (30 minutes)
Armour design presentations (10 minutes)

Appendix B: Student Supplementary Materials

Student Name: ____________________

Group Members: ____________________

____

____

Date: ____________________

Course: ____________________

Instructor: ____________________

ROYAL ARMOURIES

Secret State

Time: 10 minutes

Materials:

-300g corn flour

-250cm³ water

Lab Equipment:

-metal mixing bowl

-spoon

Introduction

Background:

In this experiment, your group is going to create a dilatant material, also known as a shear-thickening fluid, using only corn flour and water. The viscosity ("thickness") of dilatant materials increases as the force, or shear, on them increases. When pressure is applied to the corn flour substance it will become a solid. If pressure is no longer applied, it will return to a liquid state.

Experiment

Procedure:

1. Mix the corn flour with the water in the metal mixing bowl.

2. Stir the mixture until it becomes difficult to move the spoon. Tip the bowl and then stir the mixture again vigorously.

3. Drip your finger slowly in the liquid until it touches the bottom of the bowl. Then pull it out in a hurry and it will solidify.

4. Quickly drag your fingers through the liquid and lift out a putty-like ball that you can work in your hands. Be sure to keep your hands over the bowl and then open your fingers.

5. Discuss amongst your group how this is possible.

Review Questions:

1. Where else can shear thickening fluids be found?

____

____

2. How can shear thickening fluids change the way we design armour?

____

____

3. Hypothesize how a shear thinning fluid might work.

____

____

____

ROYAL ARMOURIES

Student Name: ____________________
Group Members: ____________________
____
____

Date: ____________________
Course: ____________________
Instructor: ____________________

Makin' Casein

Time: 20-25 minutes

Materials:

-125cm³ of whole milk
-40cm³ of white vinegar
-food coloring (optional)

Lab Equipment:

-filter paper
-beaker
-mixing spoon
-Bunsen burner

Introduction

Background:
Milk is a mixture of water, fat, proteins, vitamins, minerals, acids, enzymes and gases. Casein is the dominant protein making up 80% of the total milk protein. In this experiment you will separate this protein out of the milk using heat and acetic acid.

Hazards:
Use proper hand and eye protection during this experiment
Vinegar can be harmful if swallowed

Experiment

Procedure:

1. Measure the milk and place in the beaker. Slowly warm the milk, but do not boil.
2. Add several drops of food coloring to the milk so the object you form will be coloured. Remove the pan from the heat. Slowly add the vinegar into the milk in the pan.
3. Use your strainer to separate the solid that has formed from the liquid in the pan. This solid is a plastic.
4. After the liquid has drained through the strainer, pour a little water through the strainer to rinse the plastic.
5. Form the plastic into a ball and set it on a paper towel for a few minutes to remove some of the excess moisture.
6. You should then be able to form the plastic into the object of your choice.
7. When you have finished shaping your object, set it aside for a week to dry. The object will probably shrink a little as it dries out.

Review Questions:

1. What does the plastic you produced feel like? What does it remind you of?

____

____

2. Why does milk, when mixed with vinegar produce a solid?

____

____

Fun facts: Cheese is made from curds. White glue is made from the casein of the curds. The name casein comes from *caseus*, which is Latin for cheese.

ROYAL ARMOURIES

Student Name: ____________________
Group Members: ____________________
____
____

Date: ____________________
Course: ____________________
Instructor: ____________________

Makin' Casein

Time: 20-25 minutes

Materials:

-125 cm^3 of whole milk
-25 cm^3 of white vinegar
-5 cm^3 of Sodium hydrogen carbonate (baking soda)

Lab Equipment:
-beaker (250 cm3)
-stirring rod
-filter funnel
-filter paper
-paper towel
-conical flask (250 cm3)

Introduction

Background:
Milk is a mixture of water, fat, proteins, vitamins, minerals, acids, enzymes and gases. Casein is the dominant protein making up 80% of the total milk protein. In this experiment you will separate this protein out of the milk using heat and acetic acid.

Hazards:
-Use proper hand and eye protection during this experiment
-Vinegar can be harmful if swallowed

Experiment

Procedure:

1. Measure out about 125 cm^3 of whole milk into the 250 cm^3 beaker.
2. Add about 25 cm^3 of vinegar and place the beaker on the tripod under a medium heat.
3. Gently heat the beaker, stirring constantly, until small lumps begin to form.
4. Once the lumps appear, remove the beaker from the heat, and continue to stirring until the lumps stop forming
5. Allow the substance to settle, and then remove some of the liquid. Filter off the remainder of the liquid into the conical flask using the funnel and filter paper.
6. Use the paper towel to remove excess liquid from the substance.
7. Transfer the dried out substance to the empty beaker, add about 15 cm^3 of water and stir.
8. Add about 3 cm^3 of sodium hydrogen carbonate. Once bubbles of gas appear, add the remaining sodium hydrogen carbonate until it stops bubbling.
9. Stir the solid. What has been created? Hypothesize how this happened?

Review Questions:

1. Why does milk, when mixed with vinegar produce a solid?

____
____

2. What if you replace the vinegar with another acid? What about lemon juice?

____
____

Student Name: ____________________
Group Members: ____________________
____
____

Date: ____________________
Course: ____________________
Instructor: ____________________

Protecting the Future

Time: 30-40 minutes

Materials:

Everyday polymers:

- rubbish/plastic bags
- fizzy drink bottles
- milk cartons
- duct tape
- plastic gloves
- cling wrap
- tights/stockings
- Styrofoam plate
- egg carton
- plastic cups
- plastic hair clips
- chewing gum
- cardboard
- bow wrap

Introduction

Background:

The Royal Armouries has a vast collection of body protection dating back to the 15th century. Today, they strive to educate the public on not only their armour collection, but the advancements in body protection today. One example modern body protection is Kevlar, which can resist a slashing from a knife. In this activity, you will examine different types of old and new body protection. Then, in groups assigned by your instructor, create body armour of your own.

Design Activity

Procedure:

Your class has been hired by OmniGuard, a company which specializes in 'smart material' body protection. Each team is to design a prototype of a 'futuristic' type of protection using the materials supplied. The protection can be designed for any part of the body your team decides upon. Remember to consider comfort and flexibility as well as safety and durability in your design. For example, if your group is designing protection for the legs, be sure they are flexible at the knees and will allow the user to still run comfortably. Be creative in your design. Remember, it's only a prototype so anything is possible.

Review Questions:

1. What are some advancements seen in the armour over time?

____

____

2. When designing your armour, what were the most important aspects to think about?

____

____

3. How might the advancements in today's body protection change our world?

____

____

ROYAL ARMOURIES

Student Name: ____________________
Group Members: ____________________
____
____

Date: ____________________
Course: ____________________
Instructor: ____________________

'Melting' Polystyrene

Time: 10 minutes

Materials:

-20cm³ of acetone
-200cm³ of water
-Polystyrene cups
-pipette

Lab Equipment:
-2 large beakers or containers

Introduction

Background:
Polymers are made up of long chains of monomers. These long chain polymers are held together loosely by non-polar bond interactions between chains. Polystyrene is made as foam, therefore, it has air space in between these groups of polymers.

Hazards:
-Use proper hand and eye protection during this experiment
-WARNING: Acetone is a extremely flammable liquid and is harmful if swallowed, inhaled or comes in contact with skin. Use with caution!

Experiment

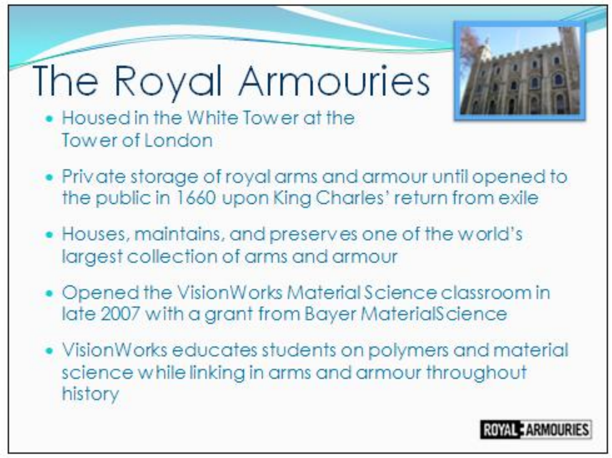
Procedure:
1. Place two large glass beakers side-by-side. Pour water into the first beaker until it's about half full and leave the second one empty.
2. Place a Polystyrene cup into the beaker that contains the water and observe what happens. The cup simply floats and is not affected by the water.
3. Place a Polystyrene cup into the empty beaker and using a pipette, take a small amount of acetone place several drops on the Polystyrene and observe what happens. The Polystyrene slowly breaks down until it appears as a glob of goo.
4. The goo that results from the dissolving Polystyrene is still the same polymer as the Polystyrene cup in a different state.

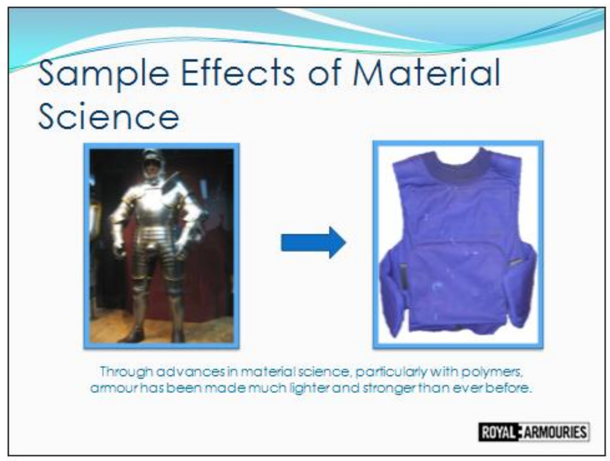
Review Questions:

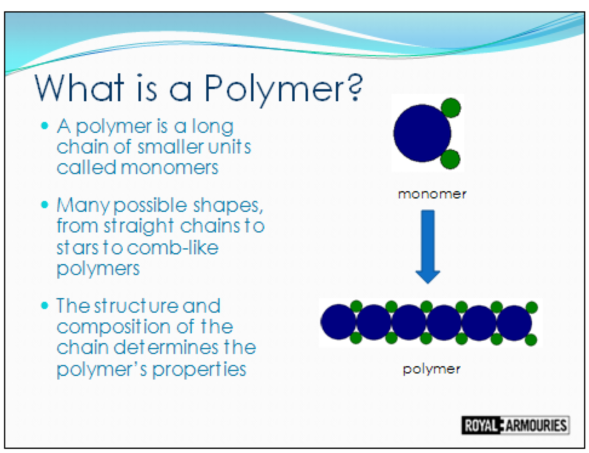
1. Predict why the acetone made the Styrofoam harden. Use the information you learned in the background section to support your answer.
____
____

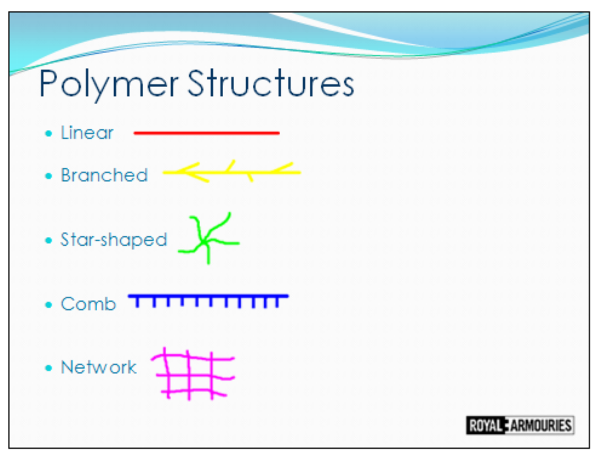
2. What properties does water have that distinguish it from acetone?
____
____

Appendix C: PowerPoint Slides



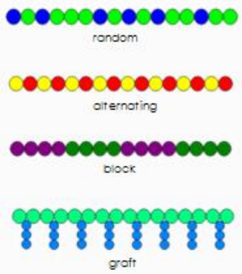






Copolymers

- *Copolymers* – polymers made up of two or more different molecules
- Types of copolymers:
  - Random
  - Alternating
  - Block
  - Graft



ROYAL ARMOURIES

Mechanical Properties

- Properties of a material relating to its behaviour when forces are applied
- Demonstrate elasticity or inelasticity
- Many different properties:
  - Malleability
  - Ductility
  - Tensile Strength and Yield Strength

ROYAL ARMOURIES

Malleability

- The ability of a material to withstand compressive (pushing) forces without fracturing
- Many metals are highly malleable, making them ideal for armour in medieval times
  - Could be formed and hammered out in forges
  - Basic armour did not require a great deal of expensive processing
- Polymers are often also malleable
  - Sheets of plastic can be softened and pressed into shape with a mold
  - Polymers used in protective devices must be malleable so that they can sustain impact without fracturing

ROYAL ARMOURIES

Ductility

- The ability of a material to withstand tensile (pulling) forces without fracturing
  - Tested by stretching a material until it breaks and then measuring its elongation
  - Materials with high ductility will be flexible, an important consideration when designing armour
- Ductile metals be drawn out into thin wires and then cut to be made into mail
- Ductile polymers can be drawn out into fibers that are then woven into Kevlar and other protective materials

ROYAL ARMOURIES

Tensile and Yield Strength

- *Tensile strength* – the amount of tensile force a material can withstand before it breaks
- *Yield strength* – the amount of force a material can withstand before permanently deforming
- These properties are essential when choosing between materials for a given purpose...picking one that is not strong enough can lead to severe consequences

ROYAL ARMOURIES

Elasticity

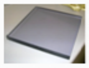
- Elasticity – a material's ability to return to its original shape after being deformed
- Polymers exhibiting elastic properties are called elastomers
- Elastic behaviour is heavily influenced by temperature
  - Too hot or cold will limit the degree of elasticity
- Important for armour
  - Limits injury to wearer
  - Improves effectiveness of armour

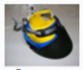
ROYAL ARMOURIES

Thermoplastics & Thermosets

- *Thermoplastics* - plastics which can be repeatedly heated and formed into various shapes, then cooled and hardened
  - Made up of long polymer chains with few cross-links, thus when heated the molecules can move apart easily and allow the plastic to be formed
  - Examples include polyamides (Nylon), polycarbonates, polyethylene and some polyesters


Makrolon


Duraflex


Desmopan

- *Thermosets* – plastics which can only be heated and formed once, are permanently set once cooled
  - Made up of extensively cross-linked polymer chains, which prevents the molecules from moving apart during heating
  - Examples include rubber, polyurethanes, epoxies, and some polyesters


Rubber

ROYAL ARMOURIES

Class Activities

ROYAL ARMOURIES

1. Balloon Kebabs

- Materials:
  - 1 rubber balloon
  - Cooking oil
  - Sharpened skewer
  - Plastic bag
  - Water
  - Sharpened pencil

1. Blow up balloon about halfway – do not overinflate.
2. Place a small amount of cooking oil on the tip of the skewer and push the sharpened end from the knot of the balloon to the nipple, being careful not to pop the balloon.
3. Discuss what happens. Why didn't the balloon pop?

ROYAL ARMOURIES

Balloon Kebabs

4. Fill a re-sealable plastic bag ¾ full with water. Push the sharpened pencil completely through the bag.
5. Why doesn't the bag leak? Is there a similarity between the bag and what happened with the balloon?
6. Discuss the properties of the bag and the balloon. Are there any other materials that have similar properties? What do you think is happening in each case?

ROYAL ARMOURIES

What Happened?

- Both the balloon and the bag are made out of polymer chains
- Adding water or air stretches the polymer chains; trying to force an object through stretches them even more
- The polymer chains on the sides of the balloon are stretched to their limit; trying to force a sharp object through would break the chains
- The chains in the bag and balloon ends could still stretch, so the needle could go between chains rather than going through and breaking them

ROYAL ARMOURIES

2. Hands-On Materials

(Chemical Formulas and Information)

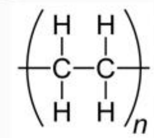
ROYAL ARMOURIES

Horn

- Naturally-occurring polymer
- Composed of the protein keratin
- Thermoplastic properties (can be repeatedly heated and moulded)
- Uses:
  - Eating utensils/dishware (the plastic does not hold the taste of food after use)
  - Combs and hair accessories
  - Spectacle frames

ROYAL ARMOURIES

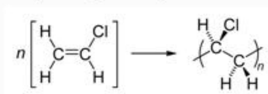
Polyethylene



- Monomer of ethylene
- Very flexible
- Uses:
  - Sandwich bags
  - Pop bottles
  - Cling wrap

ROYAL ARMOURIES

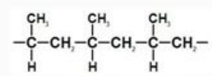
Polychloroethene (Polyvinyl Chloride)



- Monomer: Vinyl Chloride
- Commonly called PVC
- Uses:
  - Water tubing
  - Plumbing
  - Holding electrical wires

ROYAL ARMOURIES

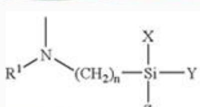
Polypropylene



- Monomer: Propylene
- Water-resistant
- Uses:
  - Stain-resistant clothing/fabrics
  - Upholstery
  - Carpets
  - Interior car trim
  - Prescription bottles
  - Rope

ROYAL ARMOURIES

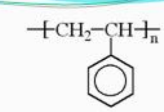
Polyurethane



- Monomer: Urethane
- Can be spun into fibers or foamed
  - Variety of stiffness, density
- Excellent insulator
- Uses:
  - Spandex/Lycra
  - Upholstery
  - Aircraft wings
  - Sail boards

ROYAL ARMOURIES

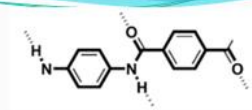
Polystyrene



- Monomer: Ethenylbenzene
- 2 main forms, hard and foamed
- Hard:
  - Food containers
- Foamed:
  - Coffee cups
  - Packing peanuts

ROYAL ARMOURIES

Kevlar



- Monomer: Para-phenylene terephthalamide
- Spun into a fiber
- 5 times stronger than the same weight of steel
- Uses:
  - Bicycle tires
  - Racing sails
  - Body armour

Makrolon

- Bayer trade name for polycarbonate
- Uses:
  - Sunglass lenses
  - DVDs
  - Apple computers
  - Bullet-proof glass

Polyamide (Nylon)

- Spun into fibers with excellent strength and wear properties

$$-\!\left[CH_2-CH_2-CH_2-CH_2-CH_2-\overset{O}{\overset{\|}{C}}-\underset{H}{\underset{|}{N}}\right]_n\!-$$

- Uses:
  - Carpeting
  - Upholstery
  - Tires
  - Brushes
  - Artificial turf
  - Clothing

Polytetrafluoroethylene (Teflon)

- Can withstand large temperature range without changing its physical properties

$$-\!\left[CF_2-CF_2\right]_n\!-$$

- Uses:
  - High-durability components
  - Non-stick coating on cooking utensils

3. Makin' Casein

- Materials:
  - 500cm³ whole milk
  - 150cm³ vinegar
  - Food coloring
  - Strainer with fairly small holes
  - Small saucepan and mixing spoon
  - Stove or heating source

1. Measure the milk and pour into the saucepan. Slowly warm the milk, but not to boiling.
2. Add several drops of food coloring to the milk. Remove the pan from the stove and slowly add the vinegar to the milk, stirring gently.
3. Using the strainer, strain the mixture so that only the solid remains. This is a plastic.

Makin' Casein

4. After the liquid has drained, rinse the solid with a little bit of water.
5. Form the solid into a ball and place on a paper towel to dry.
6. After several minutes, the plastic should be dry enough to form into a variety of shapes.
7. Once the final object has been formed, set it aside for about a week to fully dry. Slight shrinking is normal.

What Happened?

- Heating the milk and then adding an acid (the vinegar) caused the protein casein to precipitate out of the solution into clumps
- Casein is insoluble in acid, therefore it separated from the liquid solution
- Proteins are polymers made up of monomers called amino acids

4. Secret State

- Materials:
  - 300g corn flour
  - $250 cm^3$ water
  - Mixing bowl
  - Spoon


1. Mix the corn flour and water in the mixing bowl.
2. Stir the mixture until it becomes difficult to move the spoon. Tip the bowl and stir again, vigorously.
3. Slowly dip your finger into the liquid until it touches the bottom of the bowl. Then pull it out quickly – what do you notice?
4. Quickly drag your fingers through the liquid and lift out a ball of the mixture. Work it around in your hands, keeping them over the bowl and your fingers open.
5. Discuss what happens. Why do you think the mixture behaves this way?

What Happened?

- This mixture is a dilatant (shear-thickening) fluid, meaning its viscosity increases with increasing applied force
- Greater pressure means even more resistance to deformation (mixture gets even harder)
- Shear-thickening fluids could be applied to many aspects of the protection industry:
  - Military and police armour that would harden when hit by a bullet
  - Clothing that would harden upon impact from a bullet or other weapon but otherwise remain as flexible as regular clothing


5. Protecting the Future

- Your class has been hired by OmniGuard, a company which specializes in 'smart material' body protection. In the next 25-30 minutes, each team is to design a prototype of a 'futuristic' type of protection using the materials supplied. The protection can be designed for any part of the body your team decides upon. Remember to consider comfort and flexibility as well as safety and durability in your design. For example, if your group is designing protection for the legs, be sure they are flexible at the knees and will allow the user to still run comfortably. Be creative in your design. Remember, it's only a prototype so anything is possible.

Protecting the Future

- Once time is up, explain your design to the class.
  - Why did you design it the way you did?
  - What are some important properties of materials to consider when designing protection like this?

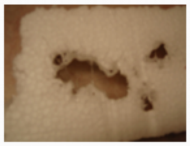

6. "Melting" Polystyrene

- Materials:
  - 2 large glass beakers or containers
  - 200 cm^3 acetone
  - 200 cm^3 water
  - Expanded polystyrene cups
  - Small plastic pipette


1. Place the beakers side-by-side. Pour water into the first beaker until it is about half-full. Pour acetone into the second beaker until it is about half-full.
2. Place one of the polystyrene cups into the beaker containing water – what happens?

"Melting" Polystyrene

3. Place a polystyrene cup into the empty beaker and using a pipette, take a small amount of acetone and place several drops onto the polystyrene. Now what do you notice?
4. The resulting goo is still polystyrene, though in a different form than it was as a cup.



ROYAL ARMOURIES

What Happened?

- The polymer chains in expanded polystyrene are loosely packed, meaning there are small pockets of air between them
- Acetone fills these air pockets and creates a denser polymer
- Both acetone and polystyrene have non-polar bonds, allowing them to dissolve each other ("like dissolves like")
- Water has polar bonds, therefore the polystyrene did not interact with it

ROYAL ARMOURIES

Extensions

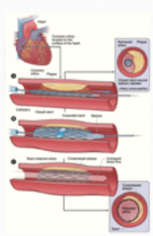
ROYAL ARMOURIES

Biomedical Applications

ROYAL ARMOURIES

Natural & Synthetic Polymers

- Natural polymers occur in the body in the form of proteins, sugars, and amino acids
- Synthetic polymers can be mass-produced in many forms
- Natural and synthetic polymers have many biomedical applications:
  - Prosthetics
  - Stents
  - Drug delivery systems
  - Implants
  - Wound closure
  - Heart valves



ROYAL ARMOURIES

Natural & Synthetic Polymers

	Advantages	Disadvantages
Natural Polymers	•Bioactive •Easier interaction with other enzymes and proteins in the body •Naturally degrade	•Can trigger immune response •Limited supply •Difficult to manufacture and modify
Synthetic Polymers	•Can be produced in large quantities •Easier to shape for desired purpose •Can be engineered to have specific properties or to perform specific functions	•May not be biocompatible •Degradation or lack thereof could require frequent removal/replacement •May have to compromise certain properties in order to obtain desired property

ROYAL ARMOURIES

Polymers in Drug Delivery

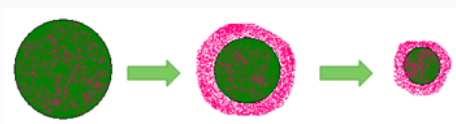
- Polymer delivery systems can be used to control how fast drugs are released into the body
  - Drug can be embedded in or attached to a polymer matrix
  - Polymers can be used to surround and protect the drug from its environment until the appropriate release time
- Polymer drug delivery also allows drugs to be delivered exactly where they are needed
  - Higher concentration can be implanted, lessening need for painful injections
  - Eliminating need for drug to travel through the body means speedier overall delivery

Polymers in Drug Delivery

- Type of degradation determines speed and type of drug delivery
  - *Bulk degradation* – occurs mostly in hydrophilic (water-loving) polymers; water enters the polymer, causing it to break down from the inside and collapse, releasing the drug all in one burst

Polymers in Drug Delivery

- *Surface erosion* – occurs mostly in hydrophobic (non water-loving) polymers; water slowly erodes the surface and over time the polymer breaks down, releasing the drug at a slower and more controlled rate



Polymers & Stents

- Stents are tubes inserted into blood vessels blocked by disease or plaque buildup
- Hold the vessel open to prevent complete blockage
- Commonly made of metal, can also be made from or coated with polymers
- Polymer stents can be coated with drugs that are intended for various uses, such as reducing plaque buildup and making the stent more biocompatible
- Currently polymer stents, though promising, frequently cause side effects such as inflammation and clotting

Heart Valves

- Replacement valves can be either biological or mechanical
- Several types of mechanical heart valves:
  - Caged ball
  - Tilting disc (one or two discs)
  - Mechanical copies of biological valves
- Polymers are used to reduce complications and make the valves more biocompatible

Smart Materials & Nanotechnology

What is Nanotechnology?

- First developed in the 1980s as a way to build molecule-sized machines[1]
- Now means "the understanding and control of matter at dimensions of roughly 1-100nm"[2]
  - 1 nm = 1 nanometer = 1 billionth of a meter
  - For comparison, a sheet of paper is 100,000 nm thick
- Combines science, engineering, and technology to allow manipulation of a material's physical, chemical, and biological properties

1. http://www.crnano.org/whatis.html
2. http://www.nano.gov/html/facts/whatIsNano.html

ROYAL ARMOURIES

Applications of Nanotechnology

- Nanotechnology is used in many industries:
  - Electronic
  - Optic
  - Biomedical/Pharmaceutical
  - Cosmetic
  - Energy
  - Materials
- Possible applications are still being investigated and developed
- Nanoparticles can be combined with other materials to improve functionality

ROYAL ARMOURIES

Polymers in Nanotechnology

- Polymers are commonly used to manufacture nanoparticles
- Wide range of properties of polymers and ease with which these properties can be changed makes them the ideal choice

Carbon Nanotubes

ROYAL ARMOURIES

Nanomaterials & Body Armour

- Nanomaterials are being used to reinforce body armour, making it stronger and more effective than ever before
  - Polymer epoxy made of spherical nanoparticles is woven into fabrics
  - Particles can be composed of silicon dioxide, titanium dioxide, or carbon nanotubes
- These materials rival the strength of steel while maintaining flexibility and a low weight

ROYAL ARMOURIES

Smart Materials

- Smart materials have one or more properties which can be altered in response to external stimuli
  - Thermo-responsive polymers deform in response to temperature changes
  - Thermo-chromatic polymers change colour in response to temperature changes
  - Electrostatic flocking "utilises a field of static electricity to orient fibres and promote their perpendicular alignment"[1] (technique used for Batman's cape in *Batman Begins*)
- Other stimuli include:
  - Stress
  - Moisture
  - pH
  - Magnetic fields

Thermo-chromatic spoons

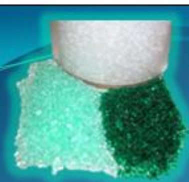
1. http://www.infind.com.au/coatings6.html

ROYAL ARMOURIES

Nanotechnology in Biomedicine

- Smart nanoparticles can be embedded onto an implant for release in response to changes in pH, drug concentration in the blood, and other stimuli
- Polymer-coated nanoparticles containing chemotherapy drugs can be released into the bloodstream to target tumors and release the drug directly on the tumor
- Nanoparticle coatings on orthopedic and dental implants could be used to release anti-infection drugs and help improve the body's ability to accept the implant

ROYAL ARMOURIES



Polymers: A Brief Overview

The Royal Armouries

- Located in the White Tower at the Tower of London
- Store and protect one of the largest collections of arms and armour in the world
- Opened a new material science education center in September 2007

What is Material Science?

- Study of materials and their properties
- Helps us understand why materials act the way they do
- Allows all kinds of products to be specially designed

Polymers

- **Polymers** - long chains of smaller units called monomers

- Shape determines properties

Copolymers

- **Copolymers** – polymers with more than one type of monomer
- Several different types:

Mechanical Properties

- Behaviour of a material when forces are applied to it
- Many different properties:
  - Malleability
  - Ductility
  - Tensile & Yield Strength
  - Elasticity

Malleability

- *Malleable* means a material can be hammered out into sheets and different shapes
- Materials for medieval armour had to be malleable
- Polymers can also be malleable

ROYAL ARMOURIES

Ductility

- *Ductile* materials can be drawn out into a thin wire
- "Chain" mail was made from metal wires bent into circular shapes and fastened together
- Ductile polymers can be woven into Kevlar and other protective materials

ROYAL ARMOURIES

Tensile & Yield Strength

- Tensile strength - how much pulling a material can take before breaking
- Yield strength – amount of force a material can take before permanently deforming

ROYAL ARMOURIES

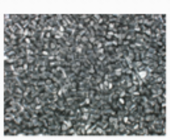
Elasticity

- Ability of a material to return to its original shape after being stretched
- Temperature affects how elastic a material is
- Armour has to have elasticity to protect the wearer

ROYAL ARMOURIES

Thermoplastics & Thermosets

- **Thermoplastics** – can be heated and shaped over and over again
- **Thermosets** – can only be heated & shaped once, then the form is permanent



Makrolon - thermoplastic

Rubber - thermoset

ROYAL ARMOURIES

Extensions

ROYAL ARMOURIES

Biomedical Applications

- The body produces natural polymers
- Synthetic polymers can be mass-produced in many forms
- Both types of polymers have many medical applications
  - Drug delivery devices
  - Stents for unblocking blood vessels
  - Replacement heart valves
  - Wound closure
  - Prosthetic devices

Smart Materials & Nanotechnology

- Nanoparticles range from 1-100 nanometers
  - 1 nanometer = 1 billionth of a meter
- Polymers have been used for a long time to manufacture nanoparticles
- Nanomaterials are being applied to many industries
  - Strengthening body armour
  - Making "smart materials" which react to their surroundings
  - Improving the effectiveness of drug delivery

Carbon Nanotubes

Thermo-chromatic spoons

Appendix D: Telephone Inquiries

Head Science Technician at Mitcham Vale
Suggestions: Historical relation is excellent, talk about weapons- gory stuff, kids love that
Interested? Yes! She liked how it incorporated different age levels. She said it could be incorporated into the classroom as well as the after school science club.

Thomas Beecham at Raynes Park
Suggestions: As long as it tied into the National Curriculum it could be used in many classes there.
Interested? Very interested. Asked several questions on how it would be set up and liked the option of bringing in the Armouries to try on the armour. Thought it was a great idea to incorporate body protection to material science because it would make the students more interesting in learning.

Ms. Jones, Sr Lab Technician at Hampton School
Suggestions: Keep it as interactive as possible, it's not everyday they get to have a hands on activity and still get the necessary information on the curriculum
Interested: Yes, wants more information when it is ready and thinks it would be a great addition to her labs.

H. Pithwa
Science Department Head at Mellow Lane, was a little skeptical at first but wants us to send her information. Made the point that teacher's schedules aren't extremely flexible. When she was told that it ties into the National Curriculum and GCSE, she sounded more intrigued by it. Email is hpithwa@hellingdongrid.org

Kish Vyas
The science department head at Queensmade, is definitely interested in the loan box and would like to receive more information on it. Wants us to email him at kvyas@hellingdongrid.org

Christine Kinham
Science Technician at St. Edward's CE. Said they'd definitely have a use for it. Used to have a science club but it's been on and off because teachers are lazy, this could help. If they can fit it in, they'd use it. Mr. Nick Hyde will be calling us back.

Heena Patel
Science Department Head at Whitmore High. Call at 12:30-1:15 or immediately after school.

Andy Malloy
Science Department Head at Chiswick High School. Talked to a chemist, Aled Hempley, who said that the project sounded fantastic. amo@chiswick.hounslow.sch.uk

Mr. Carbro

Sounded excited, very interested. The department head at Heathland School.
tjc@heathland.hounslow.sch.uk

Alan Davis
Will be looking forward to the email. Science Head at Chessington. adavis6@rbk.sch.org

Appendix E: Risk Assessment

Royal Armouries Museum

FORM RA001

GENERAL AREA RISK ASSESSMENT

Sheet No - Assessor – Location of risk assessment - Activity being assessed - Date of activity – Date assessment completed -				1 Minor Injury 2 Major Injury 3 Single Death 4 Multiple Death	1 Very unlikely 2 Unlikely 3 Likely 4 Very likely	SEVERITY TIMES LIKELHOOD GIVES	Further assessment needed i.e. COSHH/ DSE/ Manual Handling	Control Measures in place	REVISED RISK RATING TAKING INTO ACCOUNT CONTROLS
HAZARD –What is it that's causing the problem? e.g. Trailing Wire	WHO will be affected? i.e. staff/public	HOW would the hazard cause injury? e.g. wire would cause - trip/fall	ACCIDENT – What would the injury be? e.g. cut/bruise	SEVERITY	LIKELIHOOD OF HAZARD OCCURING	RISK SCORE	YES/NO		Severity (this will be the same) Likelihood should be reduced S X L = NEW SCORE
Pushing skewer or pencil through balloon	Staff	Slip/Careless	Puncture	2	1	2	No	**Staff are careful when performing demonstration**	
Heating milk over heat source	Staff, Pupils	Burn/Misbeha vior	Burn	2	1	2	No	**Pupils and staff take care around the source of heat.**	
Making armour with household materials	Pupils	Cut	Cut	1	1	1	No	**Pupils should be careful not to cut themselves when using scissors.**	
Acetone	Pupils, Staff	Misuse	Flammable, Irritant	4	2	8	No	**Teachers should conduct experiment with extreme caution; Attached CLEAPSS card must be consulted. Conducting experiment is at the teachers own discretion.**	
Acetone	Pupils, Staff	Inhalation of fumes	Drowsiness and dizziness	2	2	4	No	**Experiment must be performed in a well ventilated laboratory setting**	
Acetone	Pupils, Staff	Flammable	Burns	4	2	8	No	**Extreme caution should be taken to keep experiment away from flames.**	
Acetone	Pupils, Staff	Repeated Exposure	Irritant	2	2	4	No	**Staff and pupils must where proper laboratory attire, including gloves.**	

I as Head of the Department sign to say I have reviewed the hazards & risks and agree with the controls in place. ……………………….. Date ………..

08/02/2008

Appendix F: Loan Box Budget

Estimated Loan Box Budget

Category	Estimated Quantity	Estimated Cost per Unit	Estimated Subtotal	Notes
Shipping Costs				
Courier Costs London Extremes	1	£40.00	£40.00	www.cityoflondoncourier.co.uk
Courier Costs London Inner	1	£10.00	£10.00	www.cityoflondoncourier.co.uk
Courier Costs as far as Dartford	1	£57.00	£57.00	www.cityoflondoncourier.co.uk
Shipping Box	1	£4.39	£4.39	Royal Armouries
Total Shipping			**< £61.00**	
Experiment Resource Costs				
Bicarbonate of Soda 200g	1	£0.37	£0.37	Tesco
Acetone 150mL	1	£1.50	£1.50	Boots
Tesco Balloons 25	1	£1.00	£1.00	Tesco
Corn Flour 250g	1	£0.38	£0.38	Tesco
TDK CDR 50	1	£9.99	£9.99	http://vikingdirect.co.uk
Disposable Aprons 100	1	£2.82	£2.82	http://caboodle.co.uk
Kevlar Swatch	1	£2.00	£2.00	Royal Armouries
Kitchencraft Skewers 100	1	£2.04	£2.04	
Laminating Pockets A4 50	1	£6.94	£6.94	http://vikingdirect.co.uk
Makrolon Beads	1	£2.00	£2.00	Royal Armouries
Polystyrene Cups 25	1	£1.87	£1.87	Tesco
Polypropylene Rope	1	£2.00	£2.00	Royal Armouries
Small Plastic Containers	1	£2.25	£2.25	
Steel Balls 10	1	£12.98	£12.98	http://simplybearing.co.uk
Thermocromatic Spoons	1	£4.50	£4.50	
Toothbrush	1	£1.00	£1.00	Tesco
Tesco Press'n'Seal Sandwich Bags 60	1	£1.18	£1.18	Tesco
Tesco WhiteVinegar 568mL	1	£0.48	£0.48	Tesco
Total Resource Costs			**£55.30**	
Estimated Variable Costs 8 Groups/Class				
Aprons	1	£1.41	£1.41	Half Box of 50
Don't Break The Chain				
Balloons	5	£0.04	£0.20	
Sandwich Bags	4	£0.02	£0.08	
Skewers	2	£0.02	£0.04	
Makin' Casein				
Vinegar	2	£0.29	£0.58	150mL Per Group=> 4 Groups/Bottle
Secret State				
Corn Flower	4	£0.38	£1.52	1/2 Box per Group
Melting Polystyrene				
Acetone	1	£1.50	£1.50	
Polystyrene Cups 25	1	£1.87	£1.87	
Total Estimated Variable Costs			**£7.20**	Provides Example of 8 Group Class
Fixed Costs				
Steel Balls	10	£1.30	£13.00	
Laminated Photos	1	£0.00	£0.00	
CDR	1	£0.20	£0.20	
Kevlar Swatch	1	£2.00	£2.00	
Polypropylene Rope	1	£2.00	£2.00	
Makrolon Beads	1	£2.00	£2.00	
Small Plastic Containers	1	£2.25	£2.25	
Thermocromatic Spoons	1	£4.50	£4.50	
Toothbrush	1	£1.00	£1.00	
Shipping Box	1	£4.39	£4.39	

Category	Estimated Quantity	Estimated Cost per Unit	Estimated Subtotal	Notes
Fixed Costs Total			**£31.34**	Suggested Deposit of £35.00
Outreach Session w/ Amy Greater London				
Transport for Amy	1	£100.00	£100.00	Should be under £100 round trip
Fee for Session	1	£100.00	£100.00	
Total for Session			**£200.00**	
Variable Cost 8 Groups			**£7.20**	
Courier Cost			**£40.00**	Estimated
Total Per Session After Fixed Costs			**£47.20**	
Including Session w/ Amy			**£247.20**	
Courier Quotes				
Tower to Islington			**£11.00**	www.cityoflondoncourier.co.uk
Tower to Waltham Forest			**£34.00**	www.cityoflondoncourier.co.uk
Tower to Darford aprox. 18 miles			**£79.00**	www.todayteam.co.uk
Tower to Dartford			**£60.00**	http://www.specialdelivery.co.uk/lds.htm
Tower to Dartford			**£57.00**	www.cityoflondoncourier.co.uk
Taxi Quotes				
Tower 6-Mile Radius 20-40 mins			**£21-£24**	www.tfl.gov.uk
Tower to Dartford aprox 18 Miles			**£44.50**	http://www.expcar.com/drivers/

Appendix G:

Outreach Program Evaluation

Outreach Programme Evaluation

1. Did you find this programme useful? Why or why not?

2. Would you use this programme again in the future?

3. Did you find the extensions relevant and helpful?

4. Do you feel that this programme adequately aligns with the National Curriculum?

5. Which experiments did you use/not use? Why?

6. What improvements can be made to the programme?