Educational Outreach for the Engineering Diploma at the Royal Armouries, HM Tower of London

An Interactive Qualifying Project Report submitted to the Faculty of

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Abstract

This project integrated the UK's new Engineering Diploma (ED) into the repertoire of the Education Centre of the Royal Armouries at Her Majesty's Tower of London. Interviews with ED teachers revealed two gaps, a need for hands-on experience and flawed perceptions of engineering. The project team modified existing sessions to better fit the ED curriculum, developed joint session themes with HMS *Belfast*, proposed Careers Days, and suggested improved evaluation processes.

Acknowledgements

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Executive Summary

Over the past several decades, the UK has seen a significant decrease in the number of students pursuing Engineering as a career path, despite increased demand for engineers. In response, the government has introduced a new Engineering Diploma qualification for 14-19 year olds. The Engineering Diploma is one of seventeen Specialised Diplomas all designed to combine traditional formal learning with vocational and informal learning and to increase the number of students pursuing advanced education.

The project group assisted the Royal Armouries in developing an expanded repertoire of programmes to serve teachers and students involved in this new Engineering Diploma. To accomplish this goal we interviewed teachers to explore their needs, examined the current Royal Armouries sessions, suggested modifications to the current sessions, proposed a joint programme outline between the Royal Armouries and the HMS *Belfast* Naval Museum, updated the Royal Armouries evaluation framework, and recommended two Careers Days programmes.

Two significant challenges teachers identified in implementing the Engineering Diploma were a misconception of engineering in the UK and trouble providing applied learning to students. The Engineering Diploma requires that 50% of student learning be applied learning. Teachers from two of the schools we visited have found this challenging as the schools lack laboratory facilities. One of these teachers, Marion Watson, describes the need for applied learning, "Many [students] were interested, but now that they are in the programme it seems that they expected more hands on. We need to try to inject more practical information." Our examination of the Royal Armouries educational sessions clearly demonstrates that they can provide substantial supplemental resources, such as hands-on activities and examples of real-world engineering, that these teachers are desperately seeking.

After observation of four Royal Armouries sessions, we reviewed additional programme materials for all current sessions, and spoke with the Education Centre staff to identify engineering topics already covered in the sessions. We determined that five sessions contain engineering topics and solid links to the Engineering Diploma curriculum. These links were established by matching material covered in each session to specific Learning Outcomes defined by the qualification boards which set the Engineering Diploma curriculum. We found a total of ninety-eight Learning Outcomes were covered by these sessions.

The depth and breadth of the engineering topics covered in these five sessions was increased through modifications suggested based on our own engineering knowledge and outside research. We have proposed twenty-three modifications to these sessions which match an additional eighty-eight Learning Outcomes, a 90% increase over the coverage provided by the present offerings (Table 1).

Table 1: Number of Learning Outcomes Covered Before and After Modification

Number of Learning Outcomes (LOs) in RA Sessions			
Session Name	Current LOs	LOs with Modifications	% Increase
How Strong is Your Material	24	50	108.3%
Plastic - Fantastic?	18	40	122.2%
Modern Materials	23	32	39.1%
Sports Science	22	38	72.7%
Catapults and Trebuchets	11	26	136.4%
Total	98	186	89.8%

The Royal Armouries can further increase linkages to the Engineering Diploma curriculum by establishing a series of joint programmes with the HMS *Belfast* Naval Museum. The HMS *Belfast* is located directly across the River Thames from the Tower of London. It might appear at first to be a more logical site for engineering than the Tower; in fact, as a branch of the Imperial War Museum, the educational offerings of the HMS *Belfast* relate mostly to WWII history rather than science and engineering. Establishing a programme that uses the resources and historical engineering examples of the HMS *Belfast* to supplement the hands-on engineering sessions offered at the Royal Armouries will be mutually beneficial to both institutions.

By studying the HMS *Belfast* as a site of historic engineering significance, we identified and outlined six engineering themes that are relevant to both the HMS *Belfast* and the Tower of London. One example of these themes is the progression in the use of materials. The hulls of naval ships such as the HMS *Belfast* were traditionally made of iron and steel, but are increasingly being made of materials such as fibreglass and carbon fibre. There is a similar trend in protective armour displayed at the Royal Armouries which has progressed from iron and steel

to modern polymers such as Kevlar. All six themes identified match the Engineering Diploma curriculum and, if developed into sessions, could provide teachers with a venue for the applied learning that they are desperately seeking. In addition to topics that can be related to both the HMS *Belfast* and the Royal Armouries, we have also created three additional session themes, one relating only to the Royal Armouries and two to the HMS *Belfast* alone.

The general misconception of engineering in the UK has resulted in a relatively low number of students studying engineering. Teachers have found this effect to be particularly pronounced among women. Lazerath Fiberesima, an Engineering Diploma teacher, said:

> *People have the wrong ideas about engineering... Plumbing is not engineering, being an electrician is not engineering, being a mechanic is not engineering. [Engineers] don't have to make something; [they] can sit in an office and design and have [other] people [make the things you design]*.

To combat this problem, we have suggested that the Royal Armouries extend their partnerships with institutions such as the London Engineering Project and Smallpiece to include the Royal Academy of Engineering. In collaboration with these partnerships, the Royal Armouries should host engineering Careers Days to increase student awareness and interest in engineering. These Careers Days would be similar to the science Careers Days currently offered by the Royal Armouries, and would include a day specifically for women in engineering.

The teacher feedback methods currently used by the Royal Armouries have relatively low rates of return and do not provide sufficient constructive criticism. We outlined a new evaluation method for the Engineering Diploma sessions that includes both teacher and student feedback. The student feedback is obtained through short check-box style questions that capture information about student engagement during sessions. New teacher feedback forms use a similar format and seek information regarding the coverage of specific learning outcomes by the Royal Armouries session in question. An incentive programme has also been established to increase the rate of return of these forms.

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1 Introduction

Over the last twenty years the United Kingdom has seen a significant decrease in the number of students pursuing advanced education in science and math subjects. From 1991 to 2004 there was a 24% drop in the number of student candidates for the Physics, Chemistry, and Mathematics A-level exams despite an overall increase of 10% in the number of candidates for all subjects during the same period. As a result, it is likely that there will be a shortage of doctors, engineers, and other technical professionals in the near future. For example, a 2005 survey by the British Chambers of Commerce found that 50.4% of small firms were experiencing difficulty in recruiting adequately qualified staff (BBC, 2005).

In response to these declining enrolments in science and math education, the UK has introduced an Engineering Diploma in September 2008 as one of seventeen new Specialised Diplomas for 14-19 year olds. The Engineering Diploma has been developed in the hope it will increase the interest and qualification of people entering the fields of science, technology, engineering, and mathematics (STEM).

The Royal Armouries Education Centre has a longstanding commitment to outreach programmes in science that exploit the Tower of London's collections to supplement the formal curriculum. Through their materials science-based exhibits, on-site and outreach educational programmes they have been encouraging interest in STEM subjects among students of all ages for many years. The new Engineering Diploma programme should be no exception.

The group researched the Engineering Diploma through a series of semi-structured interviews with four teachers delivering the Engineering Diploma curriculum in Greater London schools. These interviews identified gaps teachers were struggling to fill in the curriculum such as their lack of resources for hands-on activities. The interviews also helped the group assess what material should be included in the Royal Armouries' outreach programmes.

This project assisted the Royal Armouries in expanding its repertoire of programmes. Through observation and review of five Royal Armouries sessions, the team has compiled a list of ninety-eight current links to the Engineering Diploma curriculum. Twenty-three modifications were suggested for these sessions for an additional eighty-eight curriculum links. To supplement the modification of current sessions, the team proposed six joint programme outlines with the HMS *Belfast* and three site-specific programme outlines. The team has also developed new

student and teacher feedback forms geared towards the Engineering Diploma curriculum to evaluate these sessions.

We have found that Engineering Diploma teachers are in need of hands-on sessions and that need can be filled by the Royal Armouries. We have suggested the Royal Armouries market their sessions with modifications and links to the Engineering Diploma curriculum to attract teachers. Teachers have also noted a general misconception of engineering and a lack of female participation. The Royal Armouries can help address these problems through a set of Careers Days introducing engineering professionals and topics to students. Adoption of our recommendations should help lead to a successful engineering programme at the Royal Armouries.

2 Background

A major challenge in the UK is the decline in the number of students pursuing science, technology, engineering, and mathematics (STEM) education. This section details this problem as well as the government response, the Engineering Diploma, one of seventeen Specialised Diplomas targeted towards 14-19 year olds. This section also introduces the Royal Armouries as a possible resource for the Engineering Diploma because of its experience with materials science focused educational sessions. Engineering education sessions from additional museums were also reviewed as a resource for the improvement of Royal Armouries sessions.

2.1 STEM Education:

According to the BBC (news.bbc.co.uk, 2005), there has been an overall decrease of 24% in the number of students taking A-level exams in Physics, Chemistry and Mathematics. The decline in each of these subjects is shown in Figure 1.

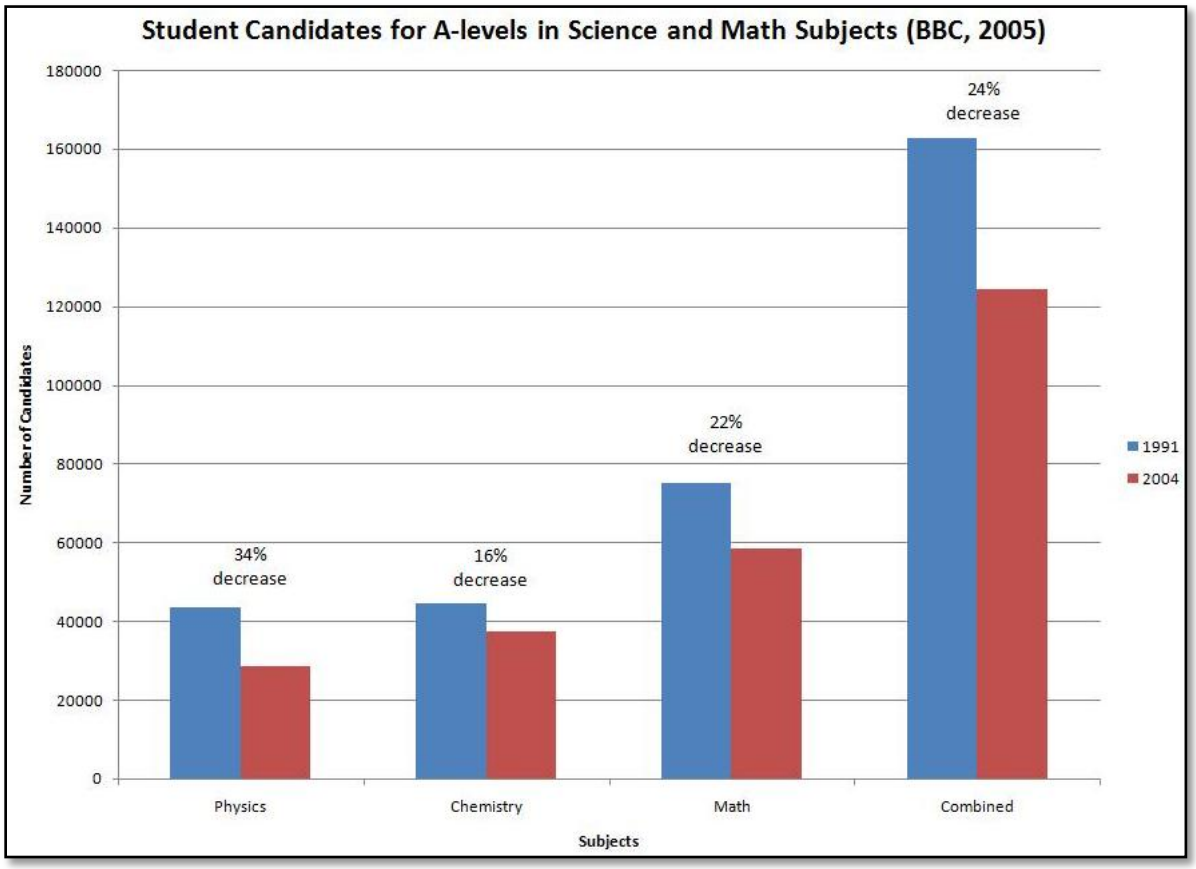


Figure 1: Students Taking A-level Exams in STEM Subjects in 1991 and 2004

Mary Ann Wolf (2008) conducted extensive assessments of high schools in the US and found similarly that there was a decrease of students involved in these technological subjects

(High Schools). Regarding the decline in the number of US students interested in pursuing STEM education Wolf says:

> *The lack of US students entering the science, technology, engineering, and math fields is one of our primary educational woes. Surveys show that the small percentage of US college students who choose to major in a math or science field gets even smaller by the end of students' freshman year. Indeed, STEM has such minimal appeal that it has come to be thought of as a "special" education for our nation's brightest students. (Wolf, 2008)*

This same trend has been seen outside of the school setting. As these students are progressing past their school career and into the workforce, this lack of knowledge and skill in these subjects has become apparent.

2.2 Education in the Workforce

In a survey conducted by the Institute of Engineering and Technology in 2007, 70% of engineering and technology companies reported that they were struggling to recruit adequately qualified staff (Bond, 2007). This reflects the declining interest in STEM education and is quite worrisome as it could result in less people entering medical and engineering professions in the near future.

Engineering has been a recent focus when designing the framework for curriculum programmes in both the United States and the United Kingdom. Since the introduction of such programmes, teachers have encountered many challenges when attempting to design lesson plans that encompass all subjects required. New pieces of legislation have been enacted in the UK addressing these problems. In 2003, the government published a green paper called Every Child Matters, and shortly following, in 2004, the Children's Act was passed. This has lead to major changes in the local curriculum to include the 14-19 reform syllabuses (DCSF, Every Child Matters, 2009). These reforms have been introduced with the knowledge that students are not prepared to enter the workforce.

The problem of unqualified employees in the UK may be in part due to the fact that students are only required to remain in compulsory education through age 16. Unfortunately, many students leave school at 16 but fail to enter the workforce. The UK Department for

Children, Schools, and Families (DCSF) collects data on the number of 16-18 year olds who are employed, in school, or enrolled in other training schemes. Figure 2 shows that the percentage of children 16-18 who were "Not currently engaged in Employment, Education or Training"(NEET) fell from a high of 19.1% in 1985 to a low of 9.1% in 1994, before rising again to a peak of 14.3% in 2001.The gradual increase in percentage, from 1994 to 2001 meant that of the entire population, over 90,000 students, were neither actively engaged in the workforce or further education in 2001. Consequently, the British government is emphasizing greater attention to STEM subjects both as a way to enhance school retention rates, but also to encourage better practical training for the workplace.

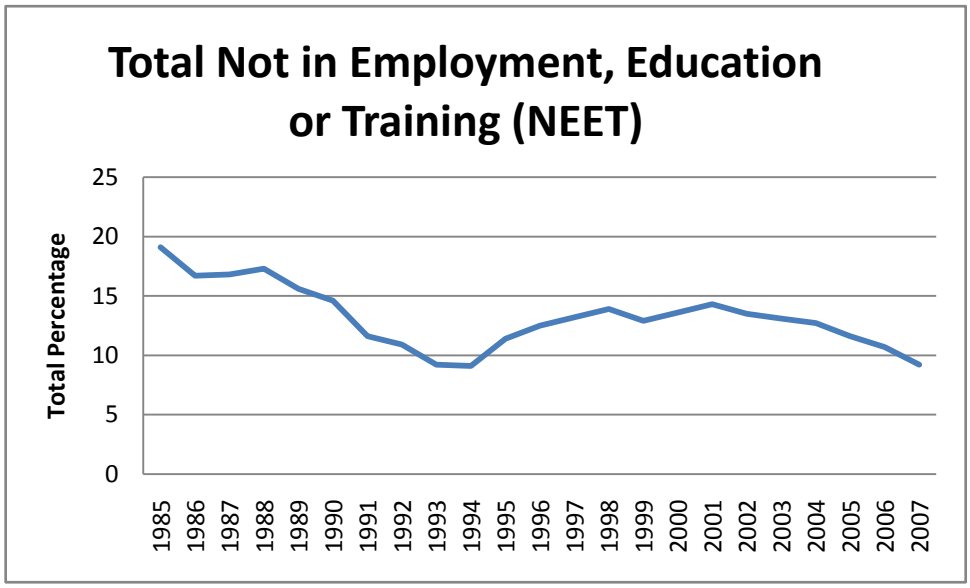


Figure 2: Percentage of 16 to 18 Year Olds who are Not Engaged in Employment, Education or Training from 1985 to 2007. Data from http://www.dcsf.gov.uk/rsgateway/DB/SFR/index.shtml

In the classrooms, students have been encouraged to work in groups to discuss and solve problems. These interactions and social situations help to prepare students for the workforce. Students should have communication skills, teamwork, leadership, and the ability to work through real-world problems. Besides these skills, they should be able to adapt to the ever-changing modern world. (College Grad, 2008)

2.3 The Education System in the UK

The Education system in the UK is divided into different Key Stages based on age (Table 2). This begins with Key Stage 0, which is nursery school, and goes up to Key Stage 5, also known as Sixth Form, which includes students in their 12th and 13th years of school.

Table 2: Key Stages in the UK

Key Stage	School Year	Age
0	Nursery	3-5 Years Old
1	Years 1-2	5-7 Years Old
2	Years 3-6	7-11 Years Old
3	Years 7-9	11-14 Years Old
4	Years 10-11	14-16 Years Old
5	Years 12-13	16-18 Years Old

As students turn fourteen and enter their 9th year they start selecting which subjects they want to focus on. They start off by taking a broad range of topics, and are only able to choose a few electives. As they progress into their 13th year, they are able to choose more classes based on their preferred subjects. Although given the ability to choose many of their own classes in the later years, all students are required to take classes in English, Maths, and Science. These studies lead to national tests, General Certificate of Secondary Education (GCSEs), in each of the subject areas (Directgov, 2005).

The GCSE exams, usually taken by students aged 16, use a grading system that enables students to earn different levels of qualifications based on the grades they receive (see Table 3). A grade from D-G on any GCSE exam earns a Level 1 qualification whereas a grade from A*-C earns a Level 2 Qualification. If students choose to continue their education they have the option to take more advanced classes which end in A-level exams, typically at age 18. In order to take A-level courses, most schools require that students receive a C grade or better (Level 2 qualification) on four to five GCSE subjects. A-Levels grant students Level 3 qualifications.

A Level 1 qualification is characterized by the improvement of "basic knowledge, understanding and skills in a subject, a specific work area or a broad economic sector." A Level 2 qualification builds upon the knowledge learned through Level 1, and a Level 3 qualification develops detailed knowledge in the particular subject of study. The Engineering Diploma

explained in more detail later, fits in with these three levels of qualifications which are displayed in Table 3 below. (Connexions Direct, 2009)

Table 3: Qualification Levels 1-3, Where the Diplomas Fit

Qualification Level	Characterization	Standardized Equivalence	Diploma Equivalence
1	Basic Knowledge in a Subject	D-G grade on GCSE exam	*The Foundation Diploma*
2	Building Upon Knowledge	A*-C grade on GCSE exam	*The Higher Diploma*
3	Develop Detailed Knowledge in Subject	A-level exam	*The Advanced Diplomas*

These qualifications are used by employers and colleges to determine student knowledge and proficiency. Typically, universities look for students who are qualified at Level 3 or more advanced levels. Students with more advanced qualifications are more likely to be selected by employers and universities (Connexions Direct, 2009).

2.4 Available Options to Students after 16

Students face several educational options when they turn 16 and finish their 11th year of schooling (Figure 3). If students plan to go to university, they may decide to enter a "Sixth Form" school and pursue additional GCSE qualifications and A-levels. Alternatively, if they wish to follow a more vocational route, students could pursue Apprenticeships with possible future employers, or turn to Work Based Learning. Work Based Learning is geared for students aged 16-18 who are not ready for work and do not wish to pursue a vocational apprenticeship or continue in an academic educational track. This programme aims to enhance participants' motivation and confidence to better prepare them for the workplace. These options also offer qualifications depending on the type work and how advanced the work is. Within the work place there is also the opportunity to take time off for study while keeping current employment. This allows students to gain knowledge through the workplace and advance their education simultaneously. Many jobs include nationally recognized qualifications which allow students to gain training through hands on experience and boost their careers (Directgov, 2005). A fourth and new option is to pursue a Specialised Diploma, which is discussed in the next section.

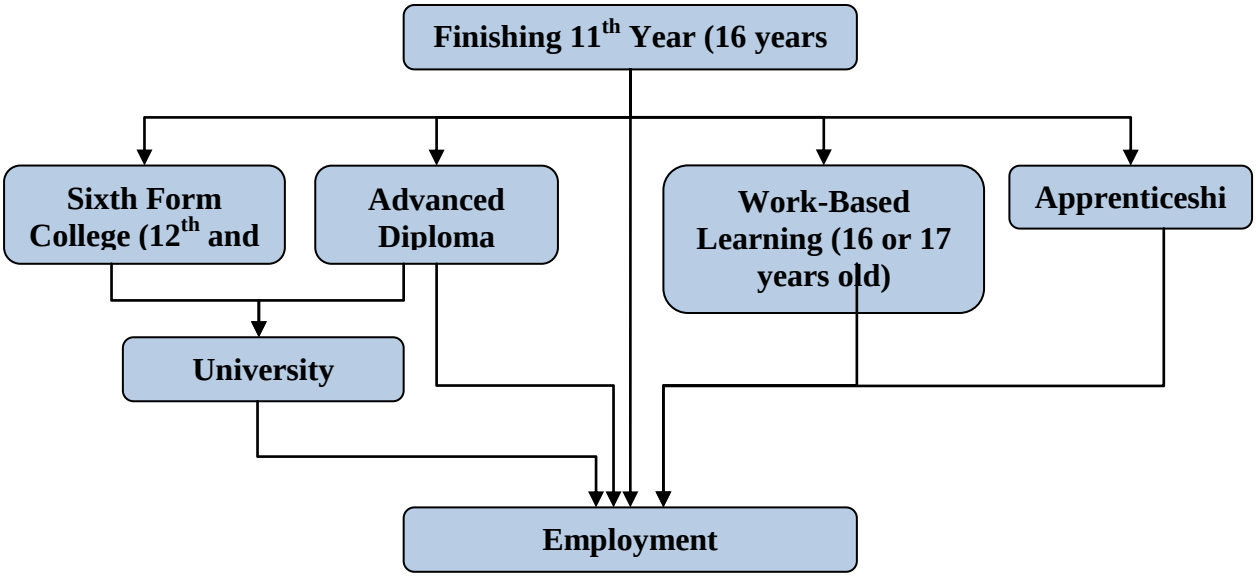


Figure 3: Flow Chart of Available Educational Options after Age 16

2.5 The Specialised Diplomas

As a part of the 14-19 Reform introduced by the UK government, a new programme, The Specialised Diplomas, has been introduced to help increase the number of students pursuing some type of advanced education. This new programme was developed in response to the complaints of employers that too many students are leaving or finishing their education without the knowledge and skills necessary to be productive and effective members of the workforce. The Specialised Diplomas are designed to provide students with an alternative to the traditional academic education paths that lead to the GCSE and A-level exams. The Diplomas combine typical academic education with vocational education to appeal to more students and encourage them to continue their schooling past the compulsory age of 16.

In September 2008, the UK began offering five Diploma programmes in over 140 schools and colleges across the UK. Five more will be offered in September of 2009 and by 2011 seventeen Specialised Diplomas will be offered across the country. These programmes focus on a variety of subjects outlined in Table 4.

Table 4: Diploma topics and dates offered

Diploma Topics	Offered Beginning
• Construction and the Built Environment • Creative and Media • Engineering • Information Technology • Society, Health and Development	September, 2008
• Environmental and Land-based Studies • Business, Administration and Finance • Manufacturing and Product Design • Hospitality • Hair and Beauty Studies	September, 2009
• Travel and Tourism • Public Services • Sport and Active Leisure • Retail Business	September, 2010
• Humanities • Languages • Science	September, 2011

Each Specialised Diploma is offered in three levels which are equivalent to the qualification levels currently used in the UK. Table 5 outlines the equivalency of each diploma level to the traditional GCSE and A-level standards. (DCSF, "Diploma in Engineering" Leaflet, 2008). Diplomas generally take about two years to complete. In the Foundation and Higher Diplomas students only work on their Diploma programmes about two days a week and spend the rest of their time learning other subjects laid out by the National Curriculum. In the Advanced Diploma, students spend most of their time working on aspects of the diploma (DCSF Diploma Website, 2009).

Table 5: Diploma Equivalencies to the Traditional GCSE and A-level Qualification System

Diploma Level	Traditional Equivalency
Foundation Diploma	5 GCSEs at grades D-G
Higher Diploma	7 GCSEs at grades A*-C
Advanced Diploma	3.5 A-levels

2.6 The Engineering Diploma

As shown in Sections 2.1 and 2.2, the decreasing number of students interested in pursuing STEM education causes a shortage of qualified engineers and scientists. As part of the United Kingdom's Education reform, the new Engineering Diploma introduces engineering concepts and relates them to the modern world. The Engineering Diploma has three main themes: The *Engineered World*, *Discovering Engineering*, and *Engineering the Future*. These themes are applied to each of the three levels of the Diploma as shown in Table 6 below (DCSF, "Diploma in Engineering" Leaflet, 2008).

Table 6: The Three Themes of the Engineering Diploma

	Themes		
	The Engineered World	Discovering Engineering	Engineering the Future
Overall Theme Description	• Importance of engineering in the modern world. • Impact of engineering on the way we live our lives.	• Introduction to basic engineering principles. • Includes discussion of design, materials, maintenance, and manufacturing.	• Methods for developing and implementing new ideas.
Example Foundation Diploma Topics	• How engineering has shaped the world in which we live. • Example: examine a model, take apart its engineered parts, and use a manual to put it together.	• How to produce simple engineering drawings and diagrams. • Example: produce sketches and plans for creation of a product.	• Impact of engineered products and processes for the future. • Example: Recycling, how different products are recycled, what they can be used for in their new lives.
Example Higher Diploma Topics	• Examine the different areas of the engineering sector. • Example: study the products and services offered by each sector and how they are used in the modern world.	• Use of simple computer software systems to design components.	• Examine the relationship between innovative engineering design and business success. • Example: develop an idea and try to get funding for it.
Example Advanced Diploma Topics	• Examine how engineering businesses operate • Example: observe how product management, research, design, manufacturing, and marketing are all important aspects of engineering companies.	• Use computer-aided design (CAD) software in an engineering context • Example: Design and produce 3-D models of objects.	• Apply math and science principles to engineering analysis, design, and problem solving.

The Engineering Diploma is made up of several sections comprising different types of learning activities. The three main themes of the Engineering Diploma fall under the category of Principle Learning. This is made up of classes specific to each diploma. Additional and Specialist Learning are courses that specialize in other chosen subjects or career ambitions. These subjects could include topics such as robotics or medical engineering. All students are required to take Functional Skills such as Math, English and Information and Communication Technology (ICT). The Specialised Diplomas also require that students study Personal, Learning, and Thinking Skills such as team-work, creative thinking, and self management. These skills are essential in the workplace regardless of the path of study that is chosen. In order to provide Diploma students with real-world experience, a Work Experience is required. As a part of this requirement, Diploma students must spend a minimum of 10 days working in a field related to their Diploma subject. Finally, all students completing a Diploma must do a Student Project in their field of study. In Engineering this could be a design project, a research project, or an evaluation or implementation of current engineering methods (DCSF, "Diploma in Engineering" Leaflet, 2008).

After completing the Foundation or Higher Diploma in Engineering students may elect to continue on to the Advanced or Progression Diploma, start an Apprenticeship, take A-levels, or start to pursue a career. After completing an Advanced Diploma, students may elect to go on to University to pursue a degree in Engineering or another subject, as the topics and skills incorporated with the Diplomas are designed to be applicable to many different careers and degrees. Students with an Advanced Diploma may also use their skills and knowledge as a foundation for work (DCSF, "Diploma in Engineering" Leaflet, 2008).

2.7 Examination Boards

There are five examination boards recognised and regulated by the Qualification and Curriculum Authority (QCA) of the UK. They are AQA (Assessment and Qualifications Alliance), EDEXCEL, OCR (Oxford, Cambridge and RSA Examinations), WJEC (Welsh Joint Education Committee) and CCEA (Council for the Curriculum, Examinations & Assessment). Three of them, AQA, EDEXCEL and OCR, are England based. WJEC primarily provides services for Wales and CCEA for Northern Ireland.

The purpose of the examination boards is to compile the curriculum specifications according to the framework set by the curriculum authority and set public exams for GCSEs and

A-Levels. Schools have the opportunity to choose from the listed agencies for their testing purposes based on their region and preferences.

The five examination boards publish their curriculum specifications, and organize the desired Learning Outcomes (LOs) for all the subjects by each applicable unit. Each LO is explained further with details outlining the subject matter it should cover. The Engineering Diploma Learning Outcomes will be used by the Royal Armouries to support the link between their current educational sessions and the school curriculum.

2.8 Youth Programmes in Museums

Museums can provide beneficial resources for both students and teachers through informal education. Museums house vast collections of modern and historical relics. These objects can be used by teachers as a tool to educate their students through the object's historical importance or other perspectives. Many museums have also adopted the use of youth programmes, in which they incorporate objects from the museum into informative sessions. These sessions help to educate students on subjects relating to the museum. These sessions may include subjects such as science, history, art, etc.

2.8.1 Outreach Programmes in the U.S.

Two museums in Massachusetts, the Higgins Armory Museum and the Boston Museum of Science, provided professional insight into the characteristics of successful outreach programmes.

The Higgins Armoury Museum offers several outreach programmes for a target audience from grade 1 (age 6) to grade 8 (age 13-14). An education interpreter gives one hour presentations using reproduction arms and armour with various hands-on opportunities. For example, in a programme for students in grade 7 called *14th Century Knight*, the education interpreter presents the alterations made in the world of arms and armour at that time and explores the reasoning behind the changes through demonstration and interaction with the audience. Their programmes are tailored to fit the visiting state's curriculum framework. They document in detail how specifically the session matches each specific subject standard of various states. We have found from this visit that hands-on activity helps engage students in the programmes (Higgins Armoury Museum, 2009).

The Boston Museum of Science provides an extensive list of school programmes for children through their outreach office called the Technology Learning Centre. After interviewing some key administrators at the Museum of Science (MoS) in Boston, we have learned of the MoS's involvement with the Lemelson Foundation. The Lemelson Foundation was established by Jerome Lemelson, a great American inventor, in order to inspire invention and scientific curiosity in the US and developing countries. The Lemelson Foundation has close ties with the Massachusetts Institute of Technology and the Smithsonian in Washington, D.C. In cooperation with MIT and the MoS, the Lemelson Foundation hosts EurekaFest, an annual, day-long event in June that brings students to the Museum for a series of design challenges. In 2008, students designed and built wind powered devices that carried large metal garbage cans three stories from the basement to the ceiling of the MoS Blue Wing. We have found that programmes introducing design to students and providing a competitive aspect keep students interested and involved with the session and allow for a greater learning experience. These ideas are further developed and integrated into the programmes offered by the Royal Armouries in our Data and Analysis chapter.

2.8.2 The Royal Armouries

As a museum, the Royal Armouries is the home to the United Kingdom's national collection of arms and armour and has the duty to take care of these objects, study them and pass them to future generations. The museum also carries out an extensive range of activities including research, film making, publications and outreach programmes related to its collections. A more detailed background of the Tower of London can be found in Appendix A.

The Education Centre of the Royal Armouries currently offers a range of student sessions for all key stages. These sessions aim to stimulate students' interests in learning through engaging sessions and hands-on activities, and inspire young people to study subjects such as history, science and engineering. Many of the sessions relate to the Royal Armouries collection of arms and armour and focus on materials science and the protective properties of different materials. The Royal Armouries' sessions are designed to fit the objectives of the National Curriculum and are offered for students from under age 5 upwards to 18 years (A-level). Table 7 presents an overview of the educational sessions offered by the museum for each Key Stage (Royal Armouries, 2009):

Table 7: Current Student Sessions the Royal Armouries Offers

Early Year Sessions	Various Sessions that involve stories and singing and are suitable for on-site and outreach programmes for children under five.
Key Stage 1	Sessions for Key Stage One children that introduce ideas of materials and their properties by handling a selection of museum objects.
Key Stage 2	All four sessions are in the State-of-the-Art learning zone: Vision Works. 1. Hard Hats 2. Walter Raleigh - Prisoner and Scientist 3. Eggstreme Sports 4. Creative Copper
Key Stage 3	1. Walter Raleigh - Prisoner and Scientist 2. How Strong is Your Longbow 3. Creative Copper 4. Murder at the Tower 5. A Very Material Mail 6. Is Plastic-Fantastic? 7. Plastic-Fantastic? SLIME 8. Materials of the Future 9. Eggstreme Sports
Key Stage 4	1. A Very Material Mail 2. Is Plastic-Fantastic? 3. Plastic-Fantastic? SLIME 4. Materials of the Future
AS and A Level	Sessions that use the armour collection to look at materials and their properties especially their strengths using the tensile strength machine. Sessions also include modern materials and future developments.
Science Outreach	1. Metal Box 2. Polymer Box 3. Object Based Material Science 4. Perfecting Progression - Amazing Armour

A typical student session lasts about one to two hours. It usually starts with a museum Objects Handling session in which students are given the chance to handle objects from the museum collection. Objects include ancient armour, such as a 14th century jousting helmet, and their modern equivalent, such as a police helmet. The Object Handling session helps students develop knowledge of how armour evolves over time. Object handling is followed by session specific activities tailored for students of different ages and needs. These activities are usually

hands-on and involve mini-experiments or competition related to materials science. The photograph below in Figure 4 shows the object handling part of the sessions.

Figure 4: Museum Object Handling Session

The Royal Armouries also offers science outreach programmes to provide outreach to teachers and students who cannot visit the Royal Armouries. Outreach can be provided through lectures and activities facilitated by Royal Armouries staff or through the Education Centre's loan box program. The loan boxes are packs of experiments and learning materials that are sent out for use by teachers in their classrooms. Each box is designed to help the teachers and students explore the relationship between material science and armour throughout history. The metal box contains experiments about the same metal materials used for ancient armours, and the polymer box is a "comprehensive programme containing ideas for experiments and discussion as well as power point displays, samples and pictures (Royal Armouries, 2009)". In lecture style object-based materials science outreach sessions, objects from the museum collection are taken to schools and information about the material properties, manufacturing processes and function of the objects is presented by a museum educator.

2.8.3 The HMS *Belfast* Naval Museum

The HMS *Belfast* Naval Museum, part of the Imperial War Museum, is a retired British war ship located directly across the River Thames from the Tower of London. It was has been turned into a museum that offers historical information about how the ship operated during war-time and what it was like to be a member of the ship's crew. The ship contains many examples of engineering as well as a new Launch! Exhibit featuring a history of shipbuilding in the UK and hands-on exhibits related to engineering. The HMS *Belfast* offers limited outreach sessions

mostly relating to history. The HMS *Belfast* could contribute to Royal Armouries' programmes with their lecture space and vast historical engineering examples.

3 Procedure

The goal of this project was to assist the Royal Armouries Education Centre in developing an expanded repertoire of programmes to serve teachers and students involved in the United Kingdom's new Engineering Diploma. To achieve this goal, the project team fulfilled three primary objectives:

- Assessed the needs of teachers and students engaged with the Engineering Diploma and adapted the current programmes offered by the Royal Armouries Education Centre to meet those needs;
- Increased the quality and quantity of engineering sessions through joint programmes between the Royal Armouries and HMS *Belfast* Naval Museum; and,
- Developed a new evaluation framework to help the Royal Armouries Education Centre better test the effectiveness of the engineering education sessions that it offers.

3.1 Assessment of the Current Implementation of the Engineering Diploma

3.1.1 Teacher Interviews

We conducted four semi-structured interviews with educators currently delivering the Engineering Diploma in the greater London area. The interviews focused on the problems and concerns of the teachers regarding the current implementation of the Engineering Diploma. These interviews have served to help the team learn more about this implementation and status of the Engineering Diploma and the needs of teachers that can be addressed by the Royal Armouries.

The Department of Children, Schools, and Families (DCSF) provided a list of 61 schools in the Greater London area that are offering the Engineering Diploma in the 2008 – 2009 academic year. We phoned all of these schools in an attempt to make contact with teachers currently teaching the Engineering Diploma. Although we were not able to speak with many teachers directly over the phone, fifteen schools provided us with e-mail addresses for Engineering Diploma teachers. An e-mail detailing the purpose of our project and the Royal Armouries interest in supplementing the Engineering Diploma curriculum was sent to those individuals and four interviews were scheduled with individuals who responded. These interviews were conducted in person either at the teachers' schools or at the Royal Armouries. For a detailed interview protocol please see Appendix X.

3.2 Adaption of Current Royal Armouries Sessions

One of the simplest ways that the Royal Armouries can integrate the Engineering Diploma into their educational programme offerings is by modifying and extending the sessions that they already offer to include Engineering Diploma topics. In order to help the Royal Armouries accomplish this, the team has completed several tasks including: examining the material and topics covered by current Royal Armouries sessions, and suggesting modifications to extend the programmes to include more material directly related to the Engineering Diploma.

3.2.1 Examination of Current Royal Armouries Sessions

In order to determine how the current Royal Armouries programmes fit into the Engineering Diploma curriculum we observed of current sessions, reviewed session materials, and matched current session topics with Engineering Diploma curriculum.

The team has observed and participated in four Royal Armouries sessions: *Materials of the Future*, *Plastic-Fantastic? SLIME*, *How Strong is Your Long Bow?*, and *Henry VIII: Man of Steel*. We sought to identify engineering related material already covered by the sessions. We were also seeking an understanding of the logistics of sessions including their time frame, facilities used, and materials available. Observing a variety of sessions allowed us to acquire a preliminary understanding of students' abilities and interest levels in different age groups. All of our findings from observation were considered when proposing session modifications, new session themes, and evaluation methods.

The team also reviewed a variety of Royal Armouries session materials including facilitators' guides, session worksheets, and descriptions in order to determine which sessions included engineering topics. The team looked for engineering topics covered and possibility for extension to include additional engineering material. Five sessions were identified as including engineering material: *How Strong Is Your Material*?, *Plastic-Fantastic?*, *Modern Materials*, *Sports Science*, and *Catapults and Trebuchets*.

Each of these sessions was matched to the Engineering Diploma curriculum using the Learning Outcomes provided by three UK examination boards (examination boards are further explained in Section 2.7). We further examined the sessions compiling a list of LOs covered. These LOs will be used by the Royal Armouries to market to teachers which sections of the curriculum are covered by their sessions.

3.2.2 Modification of Current Royal Armouries Sessions

Drawing on our engineering background, review of the literature, feedback from teacher interviews, and current implementation of programmes we generated ideas for modifications to the five relevant sessions in order to increase the amount of engineering material covered. This additional material was then matched to the Learning Outcomes of the Engineering Diploma. The suggested modifications and additional LOs help provide more coverage of the Engineering Diploma curriculum, which we hope will attract more teachers to the Royal Armouries.

We have also ranked our suggested modifications according to their ease of implementation and the number of additional Engineering Diploma links they provide. This will help the Royal Armouries decide which modifications to adopt into their sessions.

3.3 New Programme Development

In addition to the modification of current Royal Armouries sessions we have suggested the development of Engineering Diploma curriculum specific sessions as a way for the Royal Armouries to incorporate the Engineering Diploma. We have proposed some themes for these sessions and have identified the HMS *Belfast* Naval Museum as a possible partner for these sessions. All session themes have been outlined such that the Royal Armouries can use our suggestions for further development. Further development and implementation of our ideas will help the Royal Armouries aid local teachers in their instruction of the Engineering Diploma.

3.3.1 Informal Engineering Education Programmes in the US

While in the United States the group conducted informal, in-person interviews with several key informants with expertise in informal engineering education programmes who have ties to WPI (For transcripts see Appendices C and D). These individuals were identified by the project group and its advisors through their knowledge of WPI's faculty, staff, and operations. The interviewees were Erin DeSilva, an Instructional Technology Specialist from WPI's Academic Technology Center and former Educational Outreach Director for the Museum of Science (MOS) in Boston; Jeffrey Forgeng, the curator of the Higgins Armory Museum in Worcester, MA and a WPI professor of Humanities and Arts; and Martha Cyr, WPI's Director of K-12 Outreach programming.

Through the interviews, the group gained insight into the characteristics that make a successful engineering programme. We also learned about programme development and

evaluation. This information was helpful when outlining new session themes and creating new evaluation methods for the Royal Armouries.

3.3.2 Joint Programme with HMS Belfast

The team and its sponsors have also identified the possibility of using some of the resources onboard the HMS *Belfast* Naval Museum to supplement their programmes. The HMS *Belfast* is a retired British warship turned into a museum located directly across the River Thames from the Tower of London. The Royal Armouries has expressed interest in working with the HMS *Belfast* as the ship is able to provide many examples of engineering (see Section 2.8.3). A joint session with the HMS *Belfast* could include a visit of the ship including examples of engineering followed by a hands-on engineering session at the Royal Armouries.

We participated in a semi-structured interview with the chief education officer aboard the HMS *Belfast,* Barbara Ockenden, led by Royal Armouries staff, Amy Preece and Mandy Martin-Smith. This interview supplied the team with a background of the ship, an understanding of programmes currently offered on the ship, and the possibility for new programme development. We inquired about using the HMS *Belfast* to create sessions that would focus on the engineering design aspects of the ship.

The Royal Armouries expressed interest in using the ship as a resource for showing real-life examples of engineering. The team explored the ship looking for engineering topics that could be explained in an educational setting and then linked back to the Tower of London. We were able to identify six engineering themes found in both the HMS *Belfast* and the Tower of London. These six themes were then outlined with possible session discussions and activities to more easily allow the Royal Armouries to develop the topics into full programmes.

3.3.3 Additional Programme Themes

In addition to compiling a list of themes for the joint programme between the HMS *Belfast* and the Royal Armouries, we identified three site-specific themes. These topics were identified through our explorations of the HMS *Belfast*, Tower of London, and Royal Armouries sessions and exhibits. Following identification of these topics we again outlined them in more detail to provide possible session activities and discussions to be used by the Royal Armouries in the future, further development of these programmes.

3.4 Assessment of Programme Evaluation

Our discussions with the Royal Armouries education staff revealed that they need a new evaluation method for the modified and new programmes. We understand from our sponsor liaison, Amy Preece, that the return rate of the current teacher feedback form is too low. She also expressed the need to modify forms for faster and easier completion. The forms must also contain a way to extract from teachers how well a session meets the curriculum.

The group examined the current programme evaluation method of the Royal Armouries and other museums to identify the types of evaluation protocols in use and their relative strengths and weaknesses. The team then created new feedback forms for students and teachers accordingly. The new forms use both open ended questions as well as a ranking mechanism for characteristics, such as clarity, extent of curriculum coverage, and ease of understanding.

4 Data and Analysis

Through teacher interviews, we found that schools have difficulty implementing the 50% applied learning portion of the new Engineering Diploma. The Royal Armouries can assist teachers by providing supplemental hands-on activities through their programmes. Teachers have also described a common misconception about engineering in the UK and general a lack of female participation in engineering and related subjects. In order to include the Engineering Diploma into the repertoire of Royal Armouries, we have suggested modification to five current sessions, brainstormed engineering themes for the joint programme with HMS *Belfast* and developed a new evaluation framework.

4.1 Current Implementation of the Engineering Diploma

4.1.1 Teacher Interviews

The Department for Children, Schools and Families lists sixty-one schools in the greater London area as offering the Engineering Diploma in the 2008-2009 academic year (Directgov, 2009). In calling these schools we found that in fact, only fifty-two of these schools offer the programme on-site; the rest send students off-site to receive the Engineering Diploma curriculum. After contacting 52 schools that offer the ED on site, we sent e-mail requests to 15 teachers (Figure 5). Four Engineering Diploma teachers responded to our request and were subsequently interviewed.

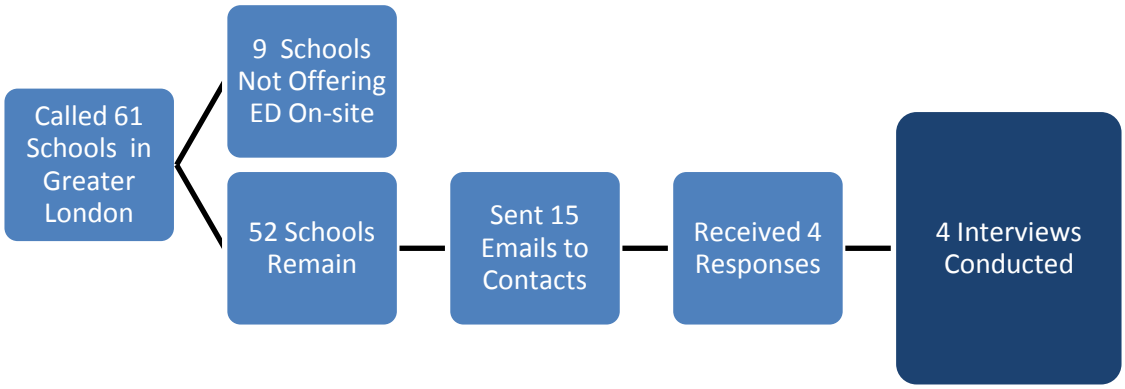


Figure 5: Procedure for Establishing Interview Contacts

We conducted and recorded semi-structured interviews with Marian Watson from Lambeth Academy, Pete Williamson from Warren School, Neil Dickson from Lambeth College, and Lazerath Fiberesima from Walworth Academy. (For transcripts see Appendices F-I)

In speaking with these teachers, we found that they have varied backgrounds. Two teachers were chosen to lead a new engineering department at their schools because of their backgrounds in civil and manufacturing engineering. Despite their backgrounds neither of these teachers had previously taught engineering subjects; one had previously been a math teacher and the other an ICT teacher in the Design and Technology (DT) department. Neither of the schools these teachers are employed in currently have a functioning laboratory facility for their Engineering Diploma students.

The third teacher taught BTEC (Business and Technology Education Council), A-Level and GCSE courses in a previously established engineering department. The fourth teacher also worked in a previously established engineering department, but had also previously worked in industry as an engineer designing injection plastics for motor vehicles. Both of these teachers had access to established and comprehensive laboratory facilities to provide experience and practical applications required by the Engineering Diploma curriculum.

The teachers, with their varied backgrounds and previous experiences, provided us with insight into the challenges that they face implementing the new Engineering Diploma. These challenges include lack of proper lab facilities and industry engagement to supply students with applied learning, a misconception of engineering among students, and lack of female participation.

4.1.2 Challenges of Hands-On Experiences for Students

The Engineering Diploma curriculum requires that students receive 50% of their engineering education as applied learning (see Section 2.7). Teachers can deliver this applied learning through hands-on activities, laboratory experience, or providing students with examples of engineering applications in real life. The last option is a challenge because few engineering companies or institutions are willing to permit students on-site. One teacher from Lambeth Academy explained,

> *The applied learning objective has been really hard to deliver because it is hard engaging employers to get involved in the Diploma. The reasons are lack of insurance and cost. To take pupils to a site you need people who are normally working off their jobs to take the students around and their production stops (see Appendix F for a synopsis of this interview)*

Only two of four schools interviewed currently have laboratory facilities, and the teachers at these schools have expressed difficulty with delivering the hands-on activities. The Royal

Armouries has the resources and lab facilities to provide applied learning that could supplement these teacher's Engineering Diploma curriculum lectures. The two schools that have lab facilities, Warren School and Lambeth College, have primarily machining facilities. One of these teachers, Pete Williamson, from Warren School mentioned, "[The laboratory facilities] do have a lot of mills, lathes, [and] drills ... [However] material sessions with a bit of hands-on [activities] sound really good. The practical stuff is where I am very interested." (See transcript in Appendix G) Schools with machining lab facilities can benefit from Royal Armouries sessions because the Materials Science curriculum can be hard to deliver as applied learning. Schools do not have access to the types of materials that the Royal Armouries offers in their sessions this creates a strong market for Royal Armouries sessions.

The lack of applied learning has resulted in disappointment among students. Marian Watson from Lambeth Academy mentions the importance of practical learning for the students involved in the programme,

> *Many [students] were interested, but now that they are in the programme it seems that they expected more hands on. We need to try to inject more practical information. (Appendix F)*

With the introduction of this new programme, teachers are clearly seeking assistance in delivering its applied learning portion.

4.2 Hands-On Opportunities at the Tower

The Royal Armouries currently offers a range of student sessions as detailed under Section 2.8.2. We identified five sessions that have particular relevance to the Engineering Diploma curriculum, and suggested modifications to them in order to cover more of the Engineering Diploma curriculum.

Currently, the Royal Armouries shows the relevance of their current sessions to the school curriculum by linking each session to the specific subjects of the National Curriculum, GCSEs and A-Levels. Of the five nationally recognised examination boards, three provide the curriculum framework for the Engineering Diploma. They are AQA, EDEXCEL and OCR. The specific Learning Outcomes for the Engineering Diploma were extracted from these three boards and attached in Appendices L, M and N. The list was used for our session modification and is provided as a reference for the Royal Armouries Education staff for use in future programme development.

In order to assess the relevance of the five sessions to the Engineering Diploma, we first matched each of the sessions to the Learning Outcomes from the three examination boards. After reviewing the session materials and the examination boards, we found that many additional links can be created through slight modifications to the sessions. The suggested modifications were made based on the ease in which they can be integrated into the sessions and the number of additional links they yield. We also ranked each modification according to these parameters and provided matrices that detail their rankings (attached in Appendix R) Rankings can be used by the Royal Armouries to determine which modifications they would like to adopt.

An example of how we did our modification comes from the session called *How Strong is Your Material?* (Appendix R). The session starts with a museum object handling session which is common to all the sessions provided by the Royal Armouries, and then it gives students the opportunity to test the strength of several different types of materials by using a tensile strength machine. Followed by machine operation, students need to record the data and do the math to calculate the elastic modulus. Finally, they need to plot a chart with numbers calculated to compare the differences on strength for the materials they are given.

Table 8 is the modification form for: *How Strong is Your Material?* The form is divided into three sections. The top section lists the LOs the session currently matches. The middle section describes current session topics and our suggested modifications. The bottom section lists the additional LOs the session would meet if the suggested modifications were adopted. Similar forms are made for the remaining four sessions and can be found in Appendix R.

This session currently has links to the LOs that relate to three main topics: basic properties of engineering materials; applying mathematics to solve engineering problems; and constructing engineering experiments and record data. In total, the session matches twenty-four LOs across all three boards.

Several modifications to this session were suggested to boost the links to the Engineering Diploma. For example, we suggest that the presenter relate the tensile strength of the material to its application (e.g. Kevlar is an ideal material for a Bouncer's Jacket due to its high tensile strength, which makes it slash-proof). By adding this modification, there will be additional links under the Engineering Diploma topic: relating the mechanical properties of the materials to its application.

Table 8: Session Modification Form

Educational Session	Exam. Board	Levels	Current Learning Outcomes Links
How Strong is your Material?	AQA	Level 1	U5LO1; U5LO2; U5LO3
		Level 2	U4LO2;
		Level 3	U3LO2; U3LO3; U8LO1; U8LO2; U8LO3; U9LO5; U9LO3; U9LO4
	EDEXCEL	Level 1	U5LO1; U5LO2; U5LO3;
		Level 2	U3LO2;
		Level 3	U3LO4; U8LO1;
	OCR	Level 1	F545LO1;
		Level 2	F550LO1; F550LO3
		Level 3	F558LO2; F563LO1; F564LO17;
Current Topics and Activities		Suggested Modification for the Engineering Diploma	
1. Museum objects handling 2. Tensile strength machine operation 3. Data recording and calculation 4. Comparison and interpretation		1. Background information about tensile strength and other mechanical properties used to describe materials (e.g. Hardness, resilience, toughness, yield strength). 2. Information about historic strength testing methods used for armours. 3. Relate the micro-structure of material to its tensile strength (e.g. Ionic, covalent, metallic boding). 4. Relate material strength to its applications (such as why to use plastic for riot shield) 5. Introduce and test some novel materials (such as QTC and smart metals). 6. Give students some sort of a problem for which they need to determine the most appropriate material through testing and analysis (similar to problem presented in "How Strong is Your Longbow?") could be continued into a mini project by teachers after visiting the RA 7. Speak briefly about the Health and Safety aspects of using the testing equipment, etc.	
Additional Links after Modification	AQA	Level 1	U5LO1(expansion)(M1); U5LO3 (M1,4); U7LO1 (M5); U5LO2(expansion)(M2)
		Level 2	U8LO1 (M5); U2LO1 (M6); U4LO1 (M6); U4LO3 (M7); U8LO2 (M6)
		Level 3	U7LO1 (M5); U3LO1 (M3,4,5,7); U9LO2(M6)
	EDEXCEL	Level 1	U7LO1 (M5);
		Level 2	U4LO3 (M1,3,4, 6); U8LO3 (M5); U4LO1 (M7)
		Level 3	U3LO1 (M3); U3LO2 (M1, 4);
	OCR	Level 1	F545LO3 (M4, M6); F547LO1 (M5); F542LO1 (M7)
		Level 2	F549LO5 (M6); F551LO1 (M6)
		Level 3	F558LO1 (M4); F558LO5 (M6) F558LO6 (M5);

As shown in Table 9, these five sessions link to ninety-eight LOs. With the modifications we suggest, the sessions would link to 186 LOs, representing an 89.8% increase.

Table 9: Number of Learning Outcomes Covered Before and After Modification

Number of Learning Outcomes (LOs) in RA Sessions			
Session Name	Current LOs	LOs with Modifications	% Increase
How Strong is Your Material	24	50	108.3%
Plastic - Fantastic?	18	40	122.2%
Modern Materials	23	32	39.1%
Sports Science	22	38	72.7%
Catapults and Trebuchets	11	26	136.4%
Total	98	186	89.8%

Table 10 below shows the distribution of the Learning Outcomes covered by each session, this table is taken from AQA examination board Level 1. In this table, an O signifies that the LO is currently covered by the session and an M signifies that the LO will be covered after modification. Under Level 1 of AQA, there are a total of twenty-one LOs. As seen in the table, seven LOs can be potentially covered by the Royal Armouries' session which indicates a 33% coverage for level1.

Table 10: Learning Outcomes Matching Matrix

	AQA Level 1						
	U2LO1	U2LO2	U3LO1	U5LO1	U5LO2	U5LO3	U7LO1
How Strong is your Material?				O	O	O	M
Plastic Fantastic?			M	O	O	O	
Modern Materials				O	O	O	O
Sports Science				O	O	O	O
Catapults and Trebuchets	M	O				M	

4.3 Joint Programmes with HMS *Belfast*

The HMS *Belfast*, a branch of the Imperial War Museum that is located just across the River Thames from the Tower of London, operates as a museum and education centre. Its resources could be used to complement and enhance the student programmes offered by the Royal Armouries. Through such a joint programme, students can take advantage of the overnight accommodation in HMS Belfast as while as the hands-on sessions provided by the Royal Armouries. Students will see engineering examples in exhibits both on the ship and in the Tower,

and this would allow schools from farther away to see both locations in one trip. A joint programme would also require a trip across Tower Bridge, providing examples of engineering while walking from one museum to the other.

In a semi-structured group interview involving Mandy Martin-Smith and Amy Preece from the Royal Armouries Education Centre and Barbara Ockenden , the former Chief Education Officer from HMS *Belfast* (transcript in Appendix E), we found that the current focus of the ship's education sessions is WWII history. Unfortunately due to the nature of the ship now being a museum, they do not have the appropriate staffing for science sessions. They also lack materials for large-scale, hands-on science activities. The machinery and many of the other mechanical aspects of the ship are inoperable due to health and safety concerns and lack of qualified staff to operate the machines.

Due to the current education given on the ship, the Royal Armouries could take advantage of the space and lecture areas on the HMS *Belfast*. The ship is a real-world model that can be used to provide examples of engineering to students. From our conversations with staff, the most feasible idea would be the creation of a self led or Royal Armouries staff led tour that would introduce some engineering topics on the ship and then engage the students in a hands-on session back at the Tower of London. The engineering themes used for the tour can be either common to both sites or specific to one of them. As such, we took tours onboard the ship, viewed the exhibits in the Royal Armouries and brainstormed the engineering concepts involved in both places.

We identified six engineering themes common to both sites, (Appendix V). These themes were outlined with background information about the engineering concepts, specific examples found in the museums, and possible hands-on activities related to the themes. The Royal Armouries can use the programme themes and outlines we provided as a starting point for the development of joint session programmes. The six joint session themes we identified are:

- Mechanical Joining Methods
- Arms and Armour
- Corrosion Resistance
- Ventilation
- Material Progression

- Load Distribution

For example, under the theme Ventilation, we have suggested that the session include background information regarding engineering concepts involved in this theme including the concept of heat transfer and three methods of heat transfer: conduction, convection and radiation. We then presented the examples of ventilation systems present on the HMS *Belfast* and in the armour collection. The ship is equipped with an air blower turbine and special air ducts to keep the steam turbine engine cool as while as preventing the heat from getting into the crew living space. Armour has small ventilation holes allowing soldiers to breathe easier without sacrificing the protective properties of their armour. Finally, we suggested some related hands on activities which could include letting students to try on pieces of armour and monitor the temperature inside or using the existing session, Staying Cool.

In addition to joint topic ideas for both the HMS *Belfast* and the Tower of London, we have developed three site-specific programme themes. The session theme we outlined for the Royal Armouries is an armour design challenge which presents students with a background of armour, a presentation on defence methods through history, and allows students to design and build their own armour with simple materials. A full description of the programme ideas can be seen in Appendix U. The emphasis of the session would be engineering design which is an important part of the Engineering Diploma.

The second session would take place on HMS *Belfast* and would be based on the ship's engine. Possible topics would include the evolution of ship engines, how the current engine works, and applied activities using engine parts and showing off the large engine rooms on the ship. The engine is a real-world example of engineering and can be used to generate interest in students enrolled in the Engineering Diploma. The session also could also have links to the curriculum with engineering design, manufacturing and control engineering. A full description of this programme is found in Appendix V.

The last of the three new programme themes is also related to the HMS *Belfast*. This session would primarily be focused on ship building. The programme could discuss the historic design of ships and more specifically, the design of the HMS *Belfast*. It could discuss the feature if the ship's separate rooms for engines and boilers to ensure function even under attack. This

programme could take advantage of the "Launch! Shipbuilding through the ages" exhibition already available on the ship and would link to the Engineering Diploma through topics of engineering design, manufacturing, materials and ergonomics. This programme can be seen in detail in Appendix V.

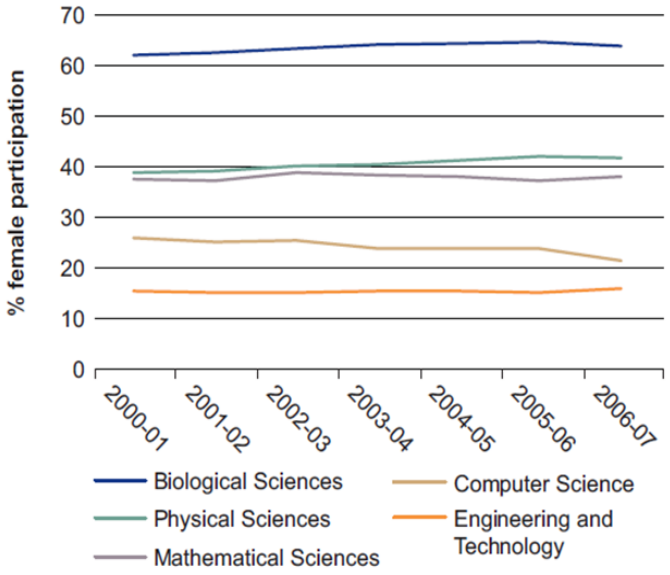
4.4 Misconception of engineering in UK

Students and adults within in the UK have a misconception of the engineering career. Many UK residents associate engineering primarily with construction and mechanics rather than design, creativity, and innovation as we do in the US. A teacher from Walworth Academy spoke of this misconception saying:

> *People have the wrong ideas about engineering... Plumbing is not engineering, being an electrician is not engineering, being a mechanic is not engineering. [Engineers] don't have to make something; [they] can sit in an office and design and have [other] people [make the things they design]... Engineering is more writing [and research] than actually doing. It is important to get those misconceptions out of [the students' heads]. (For full interview transcripts see Appendix I)*

In the UK, the word *engineer* is used to describe nearly anyone who uses modern technology to solve problems, fix things, or build things. This includes a wide range of individuals from technicians who repair appliances and the individuals who repair the London Underground to the designer of a sophisticated heating and cooling system for a modern skyscraper. In their 2007 study of "Public Attitudes to and Perceptions of Engineering and Engineers" the Royal Academy of Engineering and the Engineering and Technology Board have described this misconception: "[There is] limited initial awareness and understanding of engineering and engineers... Initial awareness and understanding of engineers and engineering tended to be narrowly defined and primarily related to construction and manual professions. This misconception causes students to expect something different and shows engineering as an undesirable career.

Women make up a very small percentage of engineering professionals and the percentage of female undergraduates in engineering hovered around 15% from 2000-2007 compared to other sciences where the female participation rates are higher (Figure 4).



Source: HESA 2008

Figure 4: Female Proportion of Undergraduates from 2000-2007

The Royal Academy of Engineering confirms this:

> *For many years only 14% of engineering undergraduates have been women and currently only 4.5% of engineering practitioners are women. Currently 25% or more of Best Programme students are female – we aim to increase this further (Best Partnership, 2008)*

We saw a similar pattern in the four schools we visited. Only 8 out of 78 (about 10%) of engineering diploma students were female. The male teacher from Walworth Academy offered his perspective:

> *The reason why we can't get girls interested is that students think engineering is messy, you can't wear a suit in engineering, you can't look good in engineering, you have to be muscular...if you are an engineer. (Appendix I)*

Teachers have mentioned that initiatives are needed to correct this misconception of engineering among students in general and particularly among women. Professional Societies that the Royal Armouries currently work with include the London Engineering Project (LEP), The Small Piece Trust and others are working in collaboration and are over seen by the Royal Academy of Engineering (RAE). The RAE was chosen to manage the ten year plan to:

- Widen Participation
- Promote Engineering

- Educate and Enthuse
- Transform schools' Science and Math

In order to accomplish these goals the Royal Academy of Engineering has introduced a series of schemes for secondary school students, undergraduates, and professional engineers. The specific goals of these schemes can be found on the Royal Academy of Engineering website. (www.raeng.org.uk/education)

4.5 Use of Careers Day to Increase Student Interest

Professional engineering organizations, such as the Royal Academy of Engineering, have tried to increase student interest in engineering through programmes called careers days. Careers days are designed to bring together students and engineering professionals in an effort to inspire and encourage engineering studies among young people. These are most effective for students who are moving into a new level of education and need to pick their options, such as year nine students who pick their GCSE subjects for the next year. Careers days are hosted by a number of different types of organizations including colleges, professional societies and trusts, and museums like the Royal Armouries.

The Royal Armouries currently offers two careers day programs directed at increasing student interest in science. One day is specifically targeted toward women in science and the other is for both men and women. On these days the Royal Armouries has a full sample of guest speakers who describe their careers in the field of science and technology and the education and experiences that enabled their success.

To serve the new Engineering Diploma, the Royal Armouries could expand their schedule of careers days to include two new careers days, one general Engineering Careers Day for both men and women and one specific to women, a 'Women in Engineering Day'. Both programmes could parallel the format of the science careers days that the Royal Armouries now offers. The introduction of these engineering careers days would serve two purposes, exposing students to a misunderstood career and highlighting to schools the Royal Armouries as a provider of applied learning.

4.6 New Evaluation Framework

Feedback from teachers is essential to determine the success of programmes. Successful programming is essential to encourage teachers to return to the Royal Armouries. Education

Staff at the Royal Armouries believe that their current evaluation form is ineffective, however, since it fails to solicit critical feedback on the content and delivery of the programs and also because response rates are typically quite low.

Currently, teachers receive forms from the Royal Armouries at the end of their visit and are asked to return them. Often teachers are very busy, and they either neglect or forget the forms. The feedback that the Royal Armouries does receive is not very useful for improving sessions because teachers do not take the time to completely fill out the forms. The teachers express satisfaction and thanks for the programme, especially since many programmes are offered free of charge, but they are reluctant to give constructive criticism.

To combat these shortcomings, we have suggested including the feedback forms in a prepaid envelope with follow up worksheets for the students. In addition to the teacher feedback forms, the Royal Armouries would like to get quick feedback from the students who took part in the session. The student feedback form would be a small detachable section of the worksheets handed out to students during a session. This form (Figure 5) is very short making it easy for students to fill in, and will provide the education staff with the information that they are looking for from the student perspective.

Today I:	Very much	Neutral	Not at All
Had fun with the Material			
Was excited about engineering			
Learned something new			
Thought the presenter did a good job teaching			
My lessons prepared me for this session			

Figure 5: Student Evaluation Form

Adding changes to the form given to teachers will also help improve the quality of feedback and hopefully increase the number of returned forms. We have provided checkboxes followed by open-ended questions. We are told by Royal Armouries staff that this format will make the evaluation forms easier and quicker for the teachers to fill out.

The current form is based on sessions involved with the national curriculum. The questions are general due to the fact that the framework needs to cover a range of STEM sessions.

We have proposed changes to tailor this existing form to the more specific framework that will be used after sessions primarily for Engineering Diploma students. The new form as seen in appendix P asks questions about the coverage of the curriculum and teacher expectations of the session. Each session contains links to Learning Outcomes in the Engineering Diploma curriculum. We have added the Learning Outcomes specific to each session in the evaluation form to teachers, asking them how well the session meets each Learning Outcome. An example of this format is shown below in Figure 6.

How well does this session match the Engineering Diploma curriculum?			
Relevant Learning Outcomes and description	Not covered	Adequately covered	Covered beyond expectation
Unit 5 LO1: Types and basic properties of engineering materials			
Unit 5 LO2: Use simple test equipment and procedures to identify material properties			
Unit 5 LO3: Select materials and processes for particular engineering applications			

Figure 6: Example Teacher Evaluation Form

In addition to filling out this chart, teachers will be asked how they specifically thought the session did not cover the Learning Outcomes mentioned in the program description. This will help the Royal Armouries by providing insight into how well a programme is being run and what could be done to improve it.

5 Conclusions and Recommendations

Teachers implementing the UK's new Engineering Diploma are facing two significant challenges; providing the hands-on experiences required by the new curriculum, and attracting students to the misunderstood engineering career. The Royal Armouries is well positioned to assist those teachers and students through its current science outreach programmes. Our findings and recommendations include a catalogue of links matching current Royal Armouries programmes to the Learning Outcomes of the Engineering Diploma, detailed recommendations for programme modifications, and targeted marketing strategies for Engineering Diploma sessions. We also suggest the implementation of two engineering Careers Days, development of several new sessions in cooperation with the HMS *Belfast*, and strategies for increasing teachers' response rates to programme evaluations.

Through our examination of the Royal Armouries' collection of education sessions we identified five programmes with engineering subjects. As shown in Table 11, these five sessions link to ninety-eight LOs from the Engineering Diploma curriculum set by the three qualification boards: AQA, EDEXCEL, and OCR. With the modifications we suggest, the sessions would link to 186 LOs, representing an 89.8% increase.

Table 11: Number of Learning Outcomes across Three Qualification Boards

Number of Learning Outcomes (LOs) in RA Sessions			
Session Name	Current LOs	LOs with Modifications	% Increase
How Strong is Your Material	24	50	108.3%
Plastic - Fantastic?	18	40	122.2%
Modern Materials	23	32	39.1%
Sports Science	22	38	72.7%
Catapults and Trebuchets	11	26	136.4%
Total	98	186	89.8%

We have ranked the suggested session modifications according to their ease of implementation and the amount of additional material covered (see Appendix S for Ranking Matrices). The Royal Armouries education staff can use these rankings to guide their choice of modifications. This will improve coverage of the Engineering Diploma curriculum, and thus better serve the teachers and students involved.

The Royal Armouries can also improve its coverage of the Engineering Diploma curriculum by offering joint sessions with the HMS *Belfast*. To many teachers the ship might appear at first to be a more logical site for engineering than the Tower and thus it may have a stronger attracting power, especially for teachers struggling to provide applied engineering. Establishing a programme that uses the resources and historical engineering examples of the HMS *Belfast* to supplement the hands-on engineering sessions offered at the Royal Armouries will be mutually beneficial to both institutions. We have identified and outlined six possible joint session engineering themes ranging from ventilation to material progression (further details can be found in Section 4.3). We recommend that the Royal Armouries staff continue working with the HMS *Belfast* to develop our outlines into new engineering sessions.

The teachers we interviewed were unaware of the hands-on science and engineering opportunities that the Royal Armouries can provide. In order to increase awareness among Engineering Diploma teachers, we recommend that the Royal Armouries market its new and modified engineering sessions to schools offering the Engineering Diploma. A list of each programme's links to the Engineering Diploma curriculum should be made available online, allowing teachers to search out and choose sessions based on their needs. A postcard providing contact information for the Royal Armouries Education Centre can briefly outline which sessions they offer to supplement the Engineering Diploma curriculum. These postcards should be sent to contacts from the fifty-two schools offering the Engineering Diploma in Greater London (contact list provided in Appendix J).

In interviews, teachers have informed us that there is a major misconception about the engineering profession in the UK, particularly among young people. In the UK, engineering is mostly thought to be associated with construction and mechanics rather than design, creativity, and innovation (BMRB, 2007). Teachers have found this effect to be particularly pronounced among women. Among the sample of four schools we visited, only 10% of their Engineering Diploma students were female. To address this problem, teachers have expressed interest in programmes that help clarify this misconception and encourage participation in engineering.

Professional societies such as the London Engineering Project and the Royal Academy of Engineering have taken an interest in educating youth about engineering and providing a better understanding about the engineering industry in the United Kingdom. By collaborating with these partnerships, the Royal Armouries can play a small, but significant role among the many

organizations with the same goal. Currently the Royal Armouries hosts two annual Careers Days, one for science in general and one for women in science. It would be beneficial for the Royal Armouries to extend these to include engineering. The goal of the Women in Science and Engineering day would be to encourage female participation in engineering and provide positive, female role models for young women considering engineering as a career.

The Royal Armouries has found that their current methods for gaining feedback are largely ineffective; they have low response rates and elicit very little constructive feedback from teachers. To rate the effectiveness of all modified sessions and future joint programme sessions, we have proposed a new evaluation framework that includes both student and teacher feedback. The student feedback form is designed to be easily completed on-site and elicit information regarding student engagement and understanding. A teacher evaluation form includes check box style questions that ask the teachers to rate coverage of Learning Outcomes to elicit critical and constructive comments without being personal. Please refer to Appendix P and Q for complete forms.

The Royal Armouries offers a range of materials science focused educational sessions that we have matched to the Engineering Diploma curriculum. Collaboration with the HMS *Belfast* provides the Royal Armouries with the opportunity to further expand their coverage of Engineering Diploma topics. Through engineering Careers Days, the Royal Armouries can help address the misconception of the engineering career among UK students. New evaluation methods should help the Royal Armouries elicit constructive feedback from teachers, allowing them to continually improve their sessions.

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Appendix A: The Tower of London

The Tower of London is a historical monument located at the north bank of the River Thames in Tower Hamlets borough of London. It was founded nearly a millennium ago by William the Conqueror in 1078 for the purpose of protecting and controlling the city of London. The tower as a whole consists of more than 20 buildings surrounded by two circles of defence walls and a moat. Throughout history, it has mainly served as a royal prison along with many other functions such as treasury, zoo, Royal Mint and royal palace.

The Tower currently houses the Crown Jewels and many other historical artefacts including a large collection of arms and armour. It is also the home to the Royal Ravens, as the belief dates back to the time of Charles II that when there are no longer ravens in the Tower the Commonwealth of England would fall (Historic Royal Palaces, 2009).

Today the official name of the Tower is "Her Majesty's Royal Palace and Fortress". As one of the world heritage sites, it is of outstanding historical and architectural significance and serves as a vital symbol of national identity. It attracts more than two million visitors a year from all over the world (Historic Royal Palaces, 2009).

Appendix B: The Royal Armouries: Past and Present

Located in the White Tower, the Royal Armouries at the Tower of London is the oldest museum in Britain and one of the oldest in the world. Its origin dates back to the king's armoury of medieval time. In 1660 King Charles II ordered a restoration effort that included the establishment of two permanent public displays of royal armour: the Line of Kings and the Spanish Armoury. He also ordered the Tower to be open to display symbols and artefacts of the British Monarchy's history and glory to paying members of the public.

Early in the 19th century the Royal Armouries started to change dramatically. "Displays were gradually altered from exhibitions of curiosities to historically 'accurate' and logically organized displays designed to improve the visitor by illuminating the past" (Royal Armouries, 2009). With the expansion of its collections, the museum space inside the white tower became too small to house them all. Starting in the 1980's, three new branches of the Royal Armouries were established, they are the Royal Armouries in Leeds, in Fort Nelson, Fareham, and in Louisville, Kentucky. This allows the Royal Armouries in the Tower to concentrate on the collection which directly relates to the Tower of London while other branches can reach out to more people all around the world (Royal Armouries, 2009).

Following a re-branding, the new mission of the museum is to help make Britain a safer place. Since the 1990s, the Royal Armouries has been working with various organizations to raise public awareness and understanding conflict and safety. The museum is working in partnership with the police to remove guns and knives from the streets and, with educators to help young people deal with conflicts. The museum has developed several regional education initiatives, such as "Impact", "Flashpoint" and "Leap Confronting Conflict" to promote the new mission (Royal Armouries, 2009). As a museum, the Royal Armouries is the home to the United Kingdom's national collection of arms and armour and has the duty to take care of these objects, study them and pass them to future generations. The museum also carries out an extensive range of activities including research, film making, publications and outreach programmes related to their collections.

Appendix C: Interview with Martha Cyr from WPI

Interviewee: Martha Cyr (referred as M), Director of K-12 programme in WPI
Location: Worcester Polytechnic Institute, Worcester, Massachusetts
Date: 18th February, 2009

Us: Some of the things we wanted to touch base on were the outreach programmes. We have to develop an outreach programme, and I know that you two specialize in K-12 outreach. We wanted to see if you could provide us with insight into some of the tools you use.
Martha: Depending on the audience, a focus group can be beneficial. It is critical to know who the audience will be.
Us: We will still need to decide who the audience will be. The focus group for the youth would be 14-19 years old. We could also develop a programme for teacher PD.
Martha: It would be feasible to think about what the Royal Armouries could offer, and develop something that they could run in the future.
You need to understand the government's standards to find a correlation to what the RA could do. That would be something that would drive the teachers to be active in the programmes.
The type of question for teachers in the focus group would be:
Where is you comfort base with teaching engineering topics?
Are there areas that you HAVE to cover?
Are there a few things based on the standards that you would pick for us to help you?
Could an extension project help to build on what you are comfortable with?
Martha: Teachengineering.org is great for teachers, along with Teachersdomain.org (WGGBH) it is a condensed version of all their NOVA interactive media.
Martha: You can come at teacher PD programmes in two ways:
One specific concept they will walk away understanding
Free form, introduce a concept but have them try to modify it to fit into their lessons this leads to individual understanding (requires more time)
It is more cost effective to have the groups come to you. Going to them won't reach everyone who needs to hear the information.
Us: What programmes does WPI offer for 14-19 year olds?
Martha: Self selective groups. We need to also make sure that the programmes are attractive to women.
Keep in mind that the programme is important to the students, because a technical literacy is important these days. If you engage students, you will possibly increase the number of students who will follow an engineering path.
One focal point that you can use in the programme is the Engineering Design Process; it is relevant, engaging and current.
Students will take that knowledge to think about other things in their lives.
The evaluation piece to the programmes is the key! You need to make sure that the evaluation is completed by the people involved in the programme. It gives the future users something that they can use to tweak the programme.
Us: We will be looking into the evaluation techniques used currently at the Royal Armouries, including observation techniques for while the programme is running.
Martha: Feel free to send anything you have to us if you need feedback during the design process.

Us: we want to reach a lot of students with the programme, but we have to keep in mind that the programmes need to relate to the collections at the RA. That is why many of their programmes have a common theme of Material Science.
Martha: We have an activity where the teachers create a protective gear for a manikin out of current materials. We went out to a field where we placed shaving cream filled balloons onto the manikin, and we jousted the protective armour to see how much damage we caused. It introduced the teachers to the design process, and was so much fun.
One thing that we would stress is that you need to decide what standards you want to narrow the programme outline on. Also, when working with educators, they have to deal with classroom management. They excel at areas that may not cover the concepts, but you need to make sure that the educators do not feel intimidated.

Appendix D: Interview with Lynn Baum from Boston Museum of Science

Interviewee: Lynn Baum (Referred to as L), Boston Museum of Science
Location: Boston Museum of Science, Boston, Massachusetts
Date: 19th February, 2009

We started by giving a background to the Engineering Diploma and the education reform in the UK.
Lynn: Are you familiar with the Lemelson / MIT engineering programme? Every year we partner with them for a weekend to do an all day design challenge. During the school year, students design teams across the US are given a design challenge that they work on and come to present at the Eureka fest. They receive further funding to continue with their design.
Us: Something along those lines, where it is a reoccurring yearly would be nice because it would bring the students back into the museum.
Lynn: The Invent team programme requires teachers and resources that the UK might not have. However the overall Engineering Design concept is something that is almost counter intuitive to all engineers, and it might be something that the UK needs to involve their students with more. It involves brainstorming, and testing.
Keeping the materials simple is going to be crucial. When you start to bring in high tech equipment to teachers who don't have the knowledge or resources, you can teach them all you want but it is not going to be transferable to the classroom.
Working off a concept like design, will allow the teachers without the background, to incorporate it better.
Teachers need varying types of teacher PD programmes. You need to get a programme that has a set focus, whether it starts something as basic as getting them aware of the technology, it can still move to something complex like actually designing improvements to current technology.
Us: We want to keep it narrow, but we were thinking that Focus groups could help. Do you think that they will be helpful?
Lynn: As long as you can explain to them that the programmes can make a difference, and they need to know that the material can be transferrable to the classroom. Make the programme Credible.
You want to change the student's attitudes; you can do that by starting with something they can relate to from their own experiences. They love to share their experiences.
We offer teacher development programmes in the summer, so in the time frame you have this might be difficult. However, you might be able to find a way to bring them in first to try it out. So that they know what their students will be working with. If they approve, bring in the students, make sure you keep them involved.
There will be some imbedded evaluation techniques that will come out while you are designing. Some examples involve constant tweaking and alterations, redesigning.
If you do go with a challenge, you need to build in a way to recognize everyone. At the end everyone should feel like they accomplished something, because design is so open ended.
Us: you had mentioned that you test out your programmes on the students you have here.
Lynn: Prototyping is very helpful work, but you need to figure out who the audience is. Use the prototyping as front end evaluation. Ask questions before and after the programme.
PHOTOGRAPH the design progress of the programme!

You are going to want to do more interviews with the teachers you have identified as useful in the Engineering Diploma. See what the population is that is going into the Diploma.
Survey evaluations:
Definitely try it on like 5 or 10 people to make sure it includes the information you want, and that it makes sense.
Other Evaluations:
When observing, make sure you have their consent. If you need further consent, you can pick and choose specific groups.

Appendix E: Interview with Barbara Ockenden from HMS *Belfast*

Interviewee: Barbara Ockenden, Education Officer, HMS Belfast.
Location: HMS Belfast, London, UK
Date: 30th March, 2009

Jen: Are you familiar with the Engineering Diploma Curriculum?
Barbara: I have heard about it but I don't understand what it covers.
Jen: The Diploma combines traditional education with vocational learning. It is offered to a few levels, all of them are equivalent to the GCSE's and A-levels in the National Curriculum. So we have been working on contacting teachers who are involved with teaching the Diploma to see where the Royal Armouries, and potentially the Belfast could help. This is limited to the London area.
We need to find out who is delivering the information. Whether they are science teachers that were told they had to do this, or if they have specific teachers with an engineering background. We have been looking at the sessions currently offered at the Royal Armouries to see if there are some programmes that fit a number of Learning Outcomes required by each Unit. If so, we will mark those programmes and rename them to highlight what the cover for teachers involved. We may also need to make slight modifications to current sessions so that they can encompass more of the Diploma curriculum
If time is available, we might also be looking to create our own programme.
Katie: With that new programme, we will be looking to see if there are connections in the material involved in the Educational sessions between HMS Belfast and the Royal Armouries. As Amy mentioned to us you so have a programme that offers an overnight stay, which could be very inviting to schools that reach beyond the length of a day trip. Could you explain how that programme works a little more for us?
Barbara: The programme is provided for schools and organizations. It is offered to students over the age of 8. It started about seven years ago, and has taken off tremendously. It is offered 240 nights of the year. It's the most authentic 1950's sailor experience as we can make it with the resources here.
I will talk about the education centre in a little while. But we do not have an outreach department. So it's our way of having UK students come to us by being more accessible. There is no access to the ship at night time, due to the risk and the chance that we will be holding another function. We can't keep up with demands for participation, and our 2010 diary opens April 1st.
I don't know if Mandy mentioned it but I will be leaving in two weeks. So I will pass along your information.
Let me give you a little background to the Education Centre here. We are focused on delivering information primarily about the Second World War. The education service is part of our branch with is just one branch owned and operated by the Imperial Museums. This ship was used in the Second World War and it was one of the first to fire at D-Day. The ship was used until 1962. The bridge used to be open, but it is not like that now.
We are a team of four and we cover the seven days a week between us. Two of us work Sunday to Thursday, while the other two will work Thursday to Tuesday. It includes the weekend activities. Most of the teaching is around the ship and WWII.
My background was a little bit to do about primary school science up to the age of ten. I make no pretentions for anything further than that.

All the sessions have a lot to do with the national Curriculum, because if it doesn't tick the right boxes. In the past I have done sessions on Metals and their properties, pulleys and forces, also floating and sinking. All of them were hands on.
Space on here, although it is a big ship, the number of rooms that can actually be used is limited. Our one teaching room is set out as the moment as lecture style. There are all sorts of things going on at the moment, and over the course of the next six months that will change that.
With the Diploma and Stem coming in, I thought we are missing the trick here. It is such a big thing.
Did you go down to the Launch exhibit while you were here?
Katie: Yes.
Barbara: We want to be able to do some teaching down there, in class style. None of my colleagues are comfortable with teaching science, but the activities are not supposed to be rocket science. We want to incorporate basic materials. I don't think we can deliver a practical session here. We don't have the space, the resources, of the qualified staff. But as a catalyst, or starting point, whether it's science design engineering or technology, we do have a few little bits of that. We are looking to have other people to come in and help us to develop something. By comparison, right now, you are the experts.
We have a great volunteer group that comes in with some mechanical background and they have their own projects that they work on while they are here. We also have a technical team of about nine that cover the logistics.
Currently, we focus on the history. We have a lot of documents and books, background information that can be drawn upon.
Katie: There are a lot of strong links to machining here on the ship would you be able to incorporate that into a session.
Barbara: There a number of restrictions related to health and safety, to have demos, or activities surrounding the machining tools onboard. The machine shop does not have functioning machines.
Katie: There's also some engineering involved with the boiler and engine rooms, such as the type development of engines over time also the power system.
Barbara: Before I go on further, there is one other problem that I need to throw into the mix. The sessions are free, but as of this September we will be charging.
Mandy: There are outlets that we can use for funding of schools that may not be able to afford the sessions. They have been really excited with the sessions ever since they were able to see how Amy delivers the material. We will just have to make sure that it covers both funding for our joint sessions, as an engineering package. The package will include something at the Belfast and something at the Tower.
Barbara: doing anything practical is just complicated here. You don't even want to think about our risk assessments.
Mandy: I think Amy was very much think along the lines of maybe talk about the engineering here, and then use our facilities to deliver the practical element. It would be very much a lecture here and they'd come over to the Royal Armouries.
Barbara: It's a lot about stimulating ideas and interest in the engineering for the older ones. If they come away from here with the knowledge, it about making something learned. They can go on to learn the practical elements over there.
They can do the physical thing with you and then use our think tank to test out anything they make.

When I first started I thought about having some type of challenge where the students take something that works on the ship. It could be something as simple as cranes. They would take what they learned and make something better, it could even be computerized, or motorized, or whatever.
Have you got any stats on how many schools are doing the Engineering Diploma?
Katie: There are sixty-one schools in the Greater London Area. Of that number, there are about twelve that are listed but they actually send their students away to other schools to learn the material
Mandy: That is quite a lot of secondary schools in the London area. I suspect that it is also DT teachers being dumped with it.
Barbara: The reason why I ask is because I got the impression from talking to teachers that everyone was very frightened by it, also that they didn't know what to do with it or where to go. Is that the impression that you got?
Katie: From the responses that we have received by sending out emails to heads of departments, it does seem that teachers need assistance. One, in particular, flat out said 'YES please!' in response to our first question 'do you need help with any area of the Diploma?'
Mandy: This is why it is very important to get on it now. I think there will be a lot of schools floundering to deliver. They will be looking for other resources. It will also offer us up to a larger audience.
Amy is going in for her engineering degree.
Amy: I would like this to be the first of many projects. I know that the Diploma age of 14 to 19 is slightly older than what we talked about before, but I think that there is so much potential here. There's so little context to the applications now, so it's nice to be able to say that's what you're learning about.
Barbara: I will try to talk to the technical staff about if the machines are useable, even if they were only able to provide background knowledge. I can make no promises, but I heard rumours that they used to work, so we will look into that.
A lot of things are getting moved around, and I am not going to be replaced. My staff will be taking on all of my responsibilities, on top of everything they already have to do.
Amy: There's so much context in science, and it's nice to be able to see real application of the material. We need to be able to talk with teachers about the material that they cover in their classroom and then be able to say to them well this is what your students know, and here is a list of programmes that fits well within that.
Barbara: We are nationally funded so we have to report all of our findings. It's not all about increasing our numbers in the educational service.
We may also be able to some teacher inset.
Amy: What I would like to have these guys do is to look around and come up with some ideas from that. I would also like them to come up with some ideas so we could do a self lead programme here. I don't have any problem assisting with that. If we are doing an engineering session, I would provide the "expert" opinion and we could include the part on the Belfast as part of the package.
Perhaps if we could hold some inset, I could come and that is a great idea.
Barbara: We could also have teachers come along for an inset.
Amy: We will definitely look into having them come but from previous experience, they just don't have the time to spend outside of their other obligations. I will have the guys mention that in their interviews coming up next week.

Mandy: If we were able to get teachers in for an inset, would there be imposing on you educational sessions already booked?
Amy: All teachers are supposed to have a half day so that might work.
Mandy: Realistically, we are thinking for the next academic year. We will need to get some dates so we can start inviting schools now.
Barbara: If that session started at three and ran to five, it's not a problem. If they want to take a walk around the ship, it might be a problem. We could have them come either earlier or a preliminary trip. The cost of the teachers would be covered, that would be kind of an incentive for them to come.
I had a gentleman come aboard who was from STEM, and he wasn't bothered at all by the boiler or engine rooms. He got very excited by the bunks in the sick room. You can unclip them, so they can rock with the ship, and then you can clip them back.
Katie: They carry that same idea for seismic earthquakes in California. Whole buildings are suspended like that so they can rock and not be structurally damaged.
Amy: That's what we're looking for, because you can take that example of the bunks and show them where the engineering concepts are applied. Behind that there is so much design and engineering technology.
There are so many links and that's what I want the guys to provide, not a self lead guide.
These guys should be looking at, perhaps the themes. The themes like the engines, the cranes. Put brief ideas down for me. We can then sit down and try to develop something from these topics. During interviews with teachers they should mention HMS Belfast and possibly an inset.
Mandy: We need it to tick all the boxes. Also, have it relate to something here and something there.
Jen: So what we come up with doesn't need to relate the HMS Belfast to what we do over at the Royal Armouries?
Mandy: We want the students to come out with an overview of engineering. At the Tower they will get this aspect of engineering, and at the Belfast, they will get this. Kind of a pick and choose from the list of themes that you come up with.
They can get more of a traditional view of what most people think of engineering over here [the Belfast].
Amy: Development is very important, to show how things have changed over time.
You guys should look at the themes of the Diploma, and then come up with something on board and at the tower to go with them. So they can say, 'I am going to do Engineering World at HMS Belfast, and I am going to do Engineering Technology at the tower' something like that.

Appendix F: Interview with Marian Watson from Lambeth Academy

Interviewee: Marian Watson, Lead Practitioner for the Engineering Diploma.
Location: Lambeth Academy, London, UK
Date: 27th March, 2009

Marian: Can you provide an engineering problem that they can work though? The important aspect is that the students will work though the problem and their progress needs to be evident. They will need to have specific and very different roles. They have to present their own findings in the form of a report.
Note: *we do not have the resources to provide projects for the engineering students, but we do have the materials to set up workshops.*
Katie: We have a programme about polymers that we were thinking could link into some of the material that the students need to be learning.
Marian: That would be excellent for our units, but that would be teaching. We need something that they can develop for themselves. Something that they can investigate, problems solve, and find solutions for. The project needs to be meaty and have some sort of depth. We would oversee the project and do the marking, but the project needs to link them to the engineers.
Jen: The only problem that we have is that we will only be here for five weeks, so it might not be feasible for us to help with the projects. But we can talk to Amy to see if she would like to be involved. To see if that is an approach that they would like to take.
Marian: They would start late in the summer months with the project, end of June beginning of July.
Katie: Design is one route we were thinking as a possibility.
Jen: It sits at core of Engineering. We will definitely talk with the education centre about the project. Is there anything with the Units and the material involved with the Diploma that you find yourself needing help with? Would you be interested in coming to the Tower for the session?
Marian: At the moment the students are in their first year of the Diploma so they are 14-15 and I would like to take some of my A-levels along.
Jen: We offer a lot about materials, and we also have a tensile testing machine. They have the opportunity for hands on testing.
Katie: Even though we will not be here, Amy Preece will be able to administer the session based on the outline that we provide. The important part will be to tailor the programme
Marian: We divide the units and deliver them to the students. The engineering students do not get to the level where specific equations are introduced, but the A levels are.
Katie: So they are introduced into the basic concepts?
Marian: Right, What I think they have done, is that they have out the taken out the important concepts of engineering. The students are given the information to provide them with and understanding if the world of work.
Jen: It sounds like the teachers aren't having issues with teaching the material. It seems like the problem is with providing real world applications. Do you think that setting up a Career day would cover what you need?
Marian: Yes, also just providing workshops with practical hands on. The students can sit through the lectures, but they would like hands on.
Katie: Are there lab facilities available at this Academy?

Marian: There are labs with useful tools for the A-level students, and they are available to the Diploma students. Our own workshop is still being set up. Schools have resources in some areas, but they may not have the resources in others.
Unit one is really learning all about engineering; like job sectors, what it means to be an engineer, and how engineering has developed over time. So that is where the Careers week would really help to cover the material.
I would love to have a career day in September or October.
Jen: how many students are doing the engineering diploma?
Marian: We have 15 students involved in their first year. So next year there will be another group of 15.
Many were interested, but now that they are in the programme it seems that they expected more hands on. We need to try to inject more practical information.
Their progress is assessed by reports, and the students do not like the idea of writing so much.
Jen explained the 'Materials of the Future'
Marian: We would like to link what they take away from the programme to a lesson for when they come back to the school.
Jen: We could try to develop something that they could take back as a follow up.
Katie: You had mentioned machining; do you think your workshop will have the materials here?
Marian: We do have simulation called design technology that they can use. LJP is the actual programme that we use. There is a range of topics that we can go into. We run though them with the students. It provides some background, a simulation, and then we are able to do testing. We have some things that the students can use. But to go out to a workshop, that would be something worth the trip.
Jen: One interesting fact about the sessions at the Royal Armouries is that the programmes need to somehow link to the Arms and Armour, so the students get to see the progression of that area of engineering, especially the progression of metal protection to plastics protection.
Marian: I teach about 50% of the material so it gets boring for the students to keep hearing for me. So a programme with a relevant activity would provide more applicable information to key topics.
Let me show you how the software works. It has simulations for engineering topics. This software was provided by the government it costs about eighty-five thousand pounds
Katie: This software could provide you with the pre information need before the session. Especially with the example you just showed us about injection moulding. That is one area that Amy could deliver a workshop for and give some industry background. It would provide the background, and we could link industry with hands on activities.
Jen: Has the industry been receptive to you contacting them?
Marian: They have been, but they would rather come into the school. It's nice for the students to see a fresh face and more information, but it's usually in the form of lecture. The students get enough of that from me. What we really want is to get them out there to meet the engineers in their work environment. But obviously the time and resources it takes to have us come out, some companies aren't willing to have us out. It takes of investment from them at the start up.
There are some companies that are very willing. But we need to find trips that will provide useful information.
Jen: That's what the Royal Armouries is aiming to do. We want to be on the cutting edge to offer a programme that can deliver the useful information.

We think that RA has a lot to offer you and Lambeth Academy. We would like to stay in contact with you. As we come up with ideas we would like to have you involved with the programme development.
Marian: Absolutely, sure. Just email me and I'll get back to you as soon as possible.
Katie: We also have an Information packet that we will send right to you once it is ready.

After speaking with you about the Engineering Diploma programme here, I am sure that other schools must be running into the same problem with finding the necessary resources.
Marian: We have some resources, but it takes time to pull them in. And you don't have a lot of time. When we sit down to write our lesson plans, you can't think to yourself where I can get an employer that is going to be able to help with this. It takes too much time to set up the meeting and setting up a trip, by that time the Unit is completed.
Jen: What is your background in engineering?
Marian: I did my B.S in Export Engineering. They want you to be a sales engineer. In our first two years we have Math, IT, Mechanics, Electronics and that sort. In my second time, I did IT and Manufacture. So I teach the Engineering Diploma and IT in the DT's. I have spent a year in the industry in Germany, and then my project year working at GEC. The only setback to working in the industry was having it be a male dominating world. So I chose to look at IT a lot more. There are a lot of links for teachers to go back into school.
There is some other engineering experience with the teachers teaching the other units.
Katie: We do have interviews with two other schools, so once we have identified the needs of all the schools, we will start creating the programme that best fits what everyone needs. We will definitely keep you updated.

Appendix G: Interview with Pete Williamson from Warren School

Interviewee: Pete Williamson, Engineering Diploma teacher.
Location: Warren School, London, UK
Date: 31st March, 2009

Jen provides background about project and Royal Armouries
Jen: What we're doing is meeting with a few teachers to find out what they are having trouble providing to the students. Also we need to determine where the Royal Armouries can help.
Pete: The biggest problems we've got are with the functional skills. In terms of getting sort of realistic Maths, Sciences, and ICTs and stuff like that. We need students to get a real context. We're not actually teaching the functional Maths in the department. The math teachers are taking care of that. So they teach it a very Maths way rather than in an engineering way or scenario.
Katie: Other teachers have mentioned that they are having trouble with getting the employment in the workforce and useable topics for the projects. Are you also having trouble with them?
Pete: Our students are really lucky in that the level three students have done their ten day work experience. They have placements Ford and other engineering sectors. We're really lucky in this area that there are so many engineering companies.
Katie: Since you have level three students, did they start at that level or did they have two years of engineering before they chose to enter the Diplomas programme?
Pete: The Engineering Diploma only started in September of 2008 so those students would have had B Tech engineering, GCSE engineering or maybe no engineering at all they may have chosen it as a sixth form option. Our level three students started in the September along with the other students in the consortia.
Katie: We offer a lot of programmes that are tailored to material science, and I know that is one of the units in the Diploma. So I've noticed that you have the facilities to do machining and the units that are included in the subject.
Pete: We do have a lot of mills, lathes, drills and things like that. We also have CNC mills and we have access to materials used in that. So that is not a problem. But anything where it's a day out for the students, and they can sit in a different environment, is interesting for them. It enables us to say 'this is what we've shown you and here's how we can show you that everything we've taught you is true, and here's an example.'
Katie: One other piece of our project is that the HMS Belfast is trying to look for a programme that can introduce students to engineering topics. They have a lot with machining on board the ship, from the actual drill presses to how the bunks are made.
Pete: Things like that are very good, because students from this area are not exposed to that type of engineering. Where we are there is a lot of power engineering. Engineering is meant to be diverse, but the students are limited to the other elements of engineering.
There was a construction project that the students did this year, just like every other year. To put a diploma spin on it, they did presentations and developed their personal thinking and learning skills (PTLs).
Katie: Most of the material science sessions have a background section where Amy shows the progression of metal protection to Plastic or Polymer protection. Each session has hands on activities with topics like memory wire and moulding plastics.
We learned that in Level one and two the in-class lectures provide a general background to the information and unit topics. At the higher levels and A-levels the students learn the equations for

the topics they learned previously. The great thing about educational sessions at the Royal Armouries is that they can be tailored to deliver the right amount of information depending on the audience.
For example, there is a session that can give a general background to topics like stress and strain to the level one and two students. That same programme can go more in depth to work in equations for stress and strain through the application of our tensile testing machine. There is also a computer programme with that that can be used as a visual aid.
Pete: Material sessions with a bit of hands on sounds really good. The practical stuff is where I am very interested.
Katie: During our research in the Engineering Units for the Diploma, we noticed that Material science is one complete unit. Do the teachers involved with the Diploma divide up the material for the units? If so which Units do you cover?
Pete: At this school we only teach Level Two and Level Three. We have two teachers delivering the level two and three for the third level. We tend to teach a unit each. Since it is the first year the schools in the consortia are all working together, which is something we've never really done before so it is really nice. It is a work in progress, because we will take what we've learned this year to fix for next year.
Katie: How did you become a Diploma Teacher here? Were you a DT teacher in previous years?
Pete: Basically three years ago the local authority did a presentation on the Diplomas. The early themes were construction, engineering, development, creative media and IT. Our local authority just got involved with the Engineering. We are the lead school for the local authority so it sort of happened by default.
Jen: So you had an Engineering programme in place before the Diplomas?
Pete: Yea, We do a level one motor vehicle qualification. We do B-TECH and GCSE Engineering. We also do A-level Engineering. We still do all those on top of the Diploma. This is the last year we will be doing the Applied A-Level engineering, because the Diploma is such a large qualification we won't have the teachers available or the time.
Katie: How many students do you have involved with the Diploma?
Pete: Currently we have eight Level two and eight Level three.
Jen: Did it catch on with the students here?
Pete: There were a few students who transferred from BTEC. Because it is so new, the parents weren't so sure that they wanted to have their children involved. At the time when the students pick for the following year, there wasn't much advertising for the Diplomas. There's a bit more now. Obviously, now there is more interest.
Katie: If we were to work on a programme would you be willing to bring some students in to participate in the session, and after provide us with feedback on how you think the session went?
Pete: Yea, absolutely.
Katie: Usually the session will last about two hours, and then the students will have access to the Tower of London. In all the sessions, the students are given an introduction to the engineering behind protection and how it has developed.
Pete: A materials session would be great because it would reinforce the materials testing that we do here. We do have access to the testing materials, but to understand the properties of the materials is very important.
There is another school in our consortia who we work a lot with. They have five Diploma students. So if we could all come together that would be nice. It's Sydney Russell.
Katie: The room that we use will be able to hold all of you together.

Have the students learn about stress and strain this year?
Pete: They haven't learned about that yet. So far we have done the interesting hands on stuff. We are going to do the Maths and the Sciences a little later. That's a bit drier. So we're hoping we can find some application stuff for the Maths and Sciences so it's not as boring for the students.
Katie: The way the material is delivered in the programme, it can be a good introduction to the material. Once the students return to the classroom, you and the other teachers can take it further by applying the relevant equations.
Pete: it might also be useful to bring along our A-Level students. There are only four of them.
Jen: Sure. The Royal Armouries does already have A-Level programmes available, but we are looking into seeing if they can be modified to fit in with the Engineering Diploma curriculum.
Pete: The kids now go to places and see different things. It's just nice and interesting for them. It's a bit more exciting than geography.
Katie: Would you like, outside of the programme, for us to provide follow up exercises? It would be something that you could take back to the classroom for a sort of link back to the programme.
Pete: We're at a stage of the Diploma that anything we can get could be useful. So even if we use it and we think 'well actually it wasn't that useful' at least we tried it. There's so little stuff out there for the Diploma. The resources that AQA provide only cover Level on and Two. There's nothing for Level 3. So anything you can provide would be useful and really well appreciated. It's an extra bit of stuff.
If we go once and see the value in it, we will pass that along in the consortia and use it at least once a year with our new students. Also if it is a good Engineering experience, it can be carried over to our BTEC and GCSE engineering students.
Jen: Are there any significant differences between the Engineering Diploma and the other Engineering programmes offered here?
Pete: So far, the main difference is this appreciation that in engineering you work as a team. GCSE and BTEC is very much individual.
With team work and collaboration the students can get so much more out of the programme. They develop useful skills (PTL's) that can be carried out into the real world. There is such a wide variety of skills that are not limited to engineering skills.
Katie: Do you have a lot of females involved in the Diploma?
Pete: It is all males. There is one A-Level, two BTEC, and three GCSE female engineering students. So anything that can we can do to enhance participation.
Katie: One thing that the Royal Armouries does to increase student interest is that they hold a Careers Day. The education centre brings in a variety of scientists and engineers. They talk about their backgrounds and how they have applied it to their work. There were three female speakers so it might be something worthwhile to have the students attend before they choose the programme they want for the following year.
Pete: We do a day with our intelligent students. Their preconception of engineering is that (a) only boys do it and (b) its boys that are actually really crap at everything else. But, they enjoy making stuff, so they do a bit of engineering or woodworking. We get very few of the really high ability students. It is the same with female students.
So we bring them down for a presentation at CEME. (Centre for Engineering and Manufacturing Excellence) They have lots of engineering facilities that they allow our local authority to use it. We try to show the females that it's not actually all getting dirty.

Katie: Exactly, the presenters talk about their own PTL's which are useful for when they apply for jobs.
Pete: We had a group of exchange students from Germany that we split into group with the student here. At first they were all really quiet, and by the end they were all really close. Getting them to write down how that change took place and what they did to get to that point is difficult for them. They broke it down into pieces of the report and got it done. Being able to write a report about finding is very necessary.
Katie: Does you school use a programme called LBGH?
Pete: No. I have been to a couple meetings where the guy has spoken about it, but I don't see it being helpful.
Katie: The programme is still in the prototype stages, but the full programme should be available this September.
Are there any other questions you have about the programmes at the Royal Armouries?
Pete: Not really, I am excited to get the students out for a session to see the practical application.
Jen: We will be sending along an information packet for you to have. It explains what the education centre does and what information is covered in their sessions.

Appendix H: Interview with Neil Dickson from Lambeth College

Interviewee: Neil Dickson, Engineering Diploma teacher.
Location: The Royal Armouries, London, UK
Date: 7th April, 2009

Amy: These guys are part of a group from Worcester Polytechnic Institute, they are all undergraduate engineers. As part of their degree requirement they have to do a project, and they've come out to London to do it.
They are very enthusiastic about engineering, and they know enough about it. They have a set of questions they want to ask you so I'll leave them to it.
Jen gave a background about the project.
Katie: We have been using the frameworks provided by the three qualification boards.
Neil: At the moment we are using EDEXCEL.
Katie: We did meet with Lambeth Academy last week. Are they in your consortia?
Neil: They are the building next to ours.
Katie: They are struggling because they do not have a workshop currently for their students. They do have the LJ Create software package though.
Neil: What happened in the consortium was all of us were given a hundred thousand pounds to deliver the diploma. Rather than everyone go off and do their own thing, all the equipment was bought ten of each. So everyone got the LJ equipment, a router, a 3-D printer, essentially it is a kit. Everyone's got exactly the same kit.
Katie: I was looking at the software, especially Unit 5 for Material Science, and thought that the software could provide a decent introduction to the students before attending our sessions. Do you find it useful?
Neil: Part of the LJ Create software if a small injection kit. Did you see it? It is kind of a one lesson, one hit sort of thing. There are only 4 small moulds with it. It works quite well, but if you have a large class it's hard for them to get the hands on.
Katie: Their kit was broken. This is where Amy's programmes can fit in really well, because the kids are given the materials. We hope they have some background information to do the practical application.
Amy: here's a packet of information about the sessions that are currently offered by the Royal Armouries. We try to make sure everything that we offer has a curriculum link. Therefore, we have to figure out the Diploma can fit in best.
Neil: What I think would be good is if you could actually assess part of the unit. So they came here but it actually goes towards part of their unit and final sort of mark. If you picked out a small part, that would be useful.
Amy: That is something we could defiantly try and help with. We have had groups in the past get useful data that they can take back and analyze.
Neil: Part of the LJ Create software has a simulation of a tensile testing as well.
Katie: We have been looking to include information from all LOs from a whole unit.
In addition to the sessions that we offer here, we have been trying to include some concepts from the HMS Belfast. There are a lot of links and applications for machining and engine type engineering. We would do a guided tour through the ship to point out those topics and discuss the engineering design behind them.
Neil: Do they still have the old communication systems onboard?

Katie: I think so, we can look into that. There is so much engineering that surrounds you, and we're trying to show that to the students. We want to point it out to the students who have misconceptions about engineering, like girls.
Neil: We have 5 girls between our two groups, which is probably the most we've had come in from the schools. I would say these five have a genuine interest in engineering.
Katie: So did you have an engineering department before?
Neil: Yea, but I've been delivering links for six years now. So we have had schools coming in. We started off with vocational GSCEs. It was very similar to the Diploma, but it slowly sank ship.
Katie: We're hoping that doesn't happen with the Diploma, there is a lot of potential with the programme, but there are a lot of schools that are just not prepared with workshops. That is where we could come in and assist.
Amy: How are you finding the levels, the abilities and achievement levels with the Diploma?
Neil: With what exactly, from what the students are attaining?
Fairly good, because we put in certain criteria so that the SATs levels are met. We insisted on them having solid basic skills first.
Amy: From your knowledge and ability with it, do you think it is something that can lead on to do it at a university or industry?
Neil: We've only delivered four units at the moment. We are delivering and running the programme it over two years. Four in the first year and four in the second year. We're also going to run the project over two years we'll have a Project Day every half term. We haven't gotten that far into it yet.
I think it depends on how much the employers vie into it. This Diplomas been designed by employers, and it to make people give them more employability. But we haven't got any employers onboard.
Part of the programmes is that the students need two weeks work experience. When it first came out, the government said it has to be related to whatever Diploma you are on. So it had to be related to engineering. They have kind of relaxed it now, so it could be two weeks in Sainsbury's or Tesco's.
Amy: There's nothing wrong with either of those places, but if you're doing an engineering qualification you need to have related work experience.
I think what might be interesting is that we do have links to the Industrial Trust and the EBP. The EBP do a lot of works experience I know. We do sessions with the Industrial Trust.
Neil: Do you do anything with the Royal Academy of Engineering?
Amy: Not at the moment, I gave the girls a contact.
Katie: We have been trying to get in contact with them.
Neil: The Royal Academy of Engineering is linked with the EBP. And there are a couple other partnerships that come out of that as well. The LEP? Phillip of Beckley? They are linked with our consortium.
I'll get you some contacts with those people; it would be good for you to get in with them. We've got another consortium meeting the first of May. That's when all ten partners will be there down at the Royal Academy of Engineering.
Katie: Is that with your qualification board?
Neil: I think the qualification board is coming to that one.
Katie: We've been trying to schedule a meeting similar for the AQA. The problem is that we are only here for a total of seven weeks. We will be presenting our findings on April 30th.

Amy: That's something that, if there's an opportunity, I could come out and present their findings.
In the materials session we do a lot of polymer science. That can be something quite dry to teach. So we try to use some of the materials behind me, like the helmet, to explain the context behind the theories. We very much want to be hands on, and interactive. That is just an example of an area that is perhaps boring for the teachers to teach and it could be something we could cover.
Neil: My background is actually in moulding and extruding. I designed plastic parts for cars. That is quite difficult to go over in a classroom. I'd like to see what you do to see where it can fit.
Katie: So you are finishing with the fourth unit now? And you'll be starting the Materials unit in the fall?
Neil: Yes.
Jen: My favourite is Materials of the Future.
Amy: The session includes; polymorph, thermoplastics, composite materials like QTC, smart metal, thermo-chromatic polymers, and cornflower if they're a good group. We want people's opinions.
Katie: So before you start teaching a lesson, how do you approach it?
Neil: The Lessons, they are meant to be very hands on, so with the funding I got I refurbished a classroom. So at one end I've got old CNC Machines that you have to programme by keying in. the next one I've got you write a programme in. The last one you draw it out and it mills it from 2-D. In the middle of the room I've got PCs so we can start off with hand drawings, and then move to CAD software packages that we've got.
In the room next door I've got the old lathes, drills, vices, benches so we try to use all three of them together.
We did a project where we built a mini London Eye. We used that project as a type of quality control and assurance. Making sure the lengths were accurate, determining which ones would be acceptable.
Katie: We don't know how much of the material we should go into, in terms of equations and the higher level understanding. If we did a tensile strength test, would they understand stress and strain?
Neil: I wouldn't go into that. The background would be young's modulus maybe a graph and that would be it.
Amy: The computer software programme that comes with the machine does produce a graph that we can put on the screen. They can perhaps analyze from there.
Neil: Lambeth is one of the poorest boroughs in Europe. It has a very diverse group really. In one group I have got seventeen students there are twelve different languages.
Amy: Do you have TAs with you to help?
Neil: Yes, it's not really worked at the moment. They're not really qualified with engineering; they were just kind of plopped in to help. So what I've done is had my BTEC National Diploma students come back to help.
Amy: It's a nice revision for them as well.
Neil: We started with 19 at level two. But it's kind of balanced out a bit. They have to do functional skills, so we put the functional skills up front and see how they cope with those. Those that are struggling with it we've moved from level two to level one. So we've got about fifteen in each.
Katie: One important aspect for the programme is that it be all encompassing for the girls as well as the boys.

Neil: The big word they like is differentiating. Differentiate for sort of different deliveries to suite all students, differentiation and inclusiveness.
Amy: Increasing STEM interest in girls is something we would be interested in. One other thing that has come out of their other interviews is not necessarily careers events, but events to show different areas of engineering and specifically for girls as well.
Neil: We've always run Women into engineering courses, or we used to run them just for women. There wasn't the uptake there, so we stopped now. But we do try to get as many involved as we can.
Katie: The great things about a careers event can be use for the first unit in level one, or to give year nine students and idea of engineering to help them decided if the Diploma is where they want to go.
Neil: At the moment it is year nine that they take their options. The way that it works at the moment is the last two years are year ten and eleven are GCSEs, and the first three years are the key stages. They are looking at three years of GCSEs, so options may drop back to year eight.
Amy: Because they know EXACTLY what they want to do with the rest of their lives then.
Neil: I've just made contact with Norwood school. They want me to take a group of year nines for sort of an entry level programme before level one, and look at the diploma for the next year. So it would be three years instead of two.
Katie: So you've brought along the EDEXCEL curriculum guidelines for Unit 5, the material science unit, is there anything in specific you would like to talk to us about?
Neil: The students have to state the different material properties, forming and identifying materials. I think to try and Identify properties on paper rather if you have hands on, then they can actually see the colour, feel the weight, and understand the other properties.
Amy: I start off every session with an armour handling. We cover the objet so you can't see what they are. They'll have an example of something that's historic and something that's modern. You can see the use of alloys and plastics. In some cases its plastics and others its Kevlar.
Neil: I don't know if you seen these learning outcomes, but it would fit in there. They also have to carry out two tests on tow engineering materials.
Katie: With the programmes that Amy offers, we are trying to create a worksheet of exercises that you can take back with you to translate back to the classroom. We want to expose the students to engineering in general.
Amy: My aim is that if one student goes away with a bit more enthusiasm for the subject and a bit more understanding and knowledge than that's a success. If we can do that for engineering, then we could get more students through the qualifications.
Neil: I think you would find our students quite challenging.
Amy: I work with lots of mixed groups. We try to make things as bespoke as possible. We cater to the people in front of us.
Katie: In situations where students maybe don't understand everything that Amy is teaching them, I think the students can still go away having some knowledge of the material. During my experiment the students could visually see changes happening after they added plastic to hot water. The material turned clear and they took note of that.
We want the session to fit in with what you will be teaching the students at the time you are booking the session. The good thing is that you will be starting Unit 5 in the fall, so there's time for us to develop a useable programme.
Neil: We were the first ones in our consortium to get our kits set up. With the LJ Create software, it's going to take years to go through it all.

It took me weeks, but I looked at their cross references between the software and the Units, and I only took bits and pieces to use. I will use when it need be. I am not overly impressed by it. It is something that they look for in inspections. Everyone needs a VLE.
I think there's too much on it. There's no way to measure how much knowledge the students are gaining from the package.
You should come to the college and have a look around.
Katie: We are going back to the Belfast tomorrow to look at the links to more of the topics that your students would be interested, as far as the application of machining to even something as simple as the bunks. That will be on top of engineering topics from each of the Diploma's three themes. We would like the focus to be on the design.
Here there is a great example of how protection has transformed from steel to plastics. Amy also has great links to other engineers that she can bring into the sessions.
Neil: The Hoover Company brings a chest to schools. It has the heads of all the vacuums, and the design behind them is just fantastic. We use that to try and bring out ideas from the students.
We do a lot of prototyping. Anything the students would make they start with card. We have drawing packages, but they are too difficult for the students. We're looking for something simpler. So we only use them to download imaged from the website and print them off.
They were looking into buying a 3-D scanner, but I can't see the benefit in taking something that's already made and scanning it and printing out into plastic. It's nice, but it doesn't do a whole lot for the students in terms of learning the design process.
If I am going to teach at all these different schools, then I would like them to all be using the same software package.
Amy: Do you have to go out then to the schools, or do they come to you? It must be a time table nightmare.
Neil: They come to us. We signed up to a common timetable, Lambeth and Southwark. Its Tuesdays and Fridays, it's known as the flexibility project. We're told to treat them like adults.
Amy: I think what would be quite nice from our point of view is maybe, if when we've adapted the session, we could offer a trial session for you group to come in and have a go.
Maybe that's something we could do next academic year?
Katie: It might fit in best there, to assist with unit 5.
Neil: When you create this session I think it's important where you pitch it. It needs to be basic. Most people still don't know what the equivalency to GCSEs and A levels. Even though they are getting GCSEs at lower grades there are points associated with them.
Katie: So how do you grade projects that your students work on?
Neil: We have to take these LOs and make into assignments, and tests. It's a horrible marking scheme. These Marks are progressive; they go further on each one. When the students achieve these, I check them off. The resource documents give a little guidance, but there are no other assignments. I have to take these and develop the worksheets myself.
At Lambeth College, we're predominantly electronics engineering. So we started off with the electronic circuit because that's our strength. One of the first assignments is that they have to recognize symbols for six components. They way we've approached that are by having them build circuits first, and then recognize the symbols and components. The assignment was that they had to draw a circuit diagram.
To recognize components, I filled in a chart with twenty components and rather than have them fill it in like a test they give me a verbal answer 'this is a resistor'. They can also recognize it by its colour codes and resistance associated with it.

Katie: Your goal is to get all the students through Mark 3 by the end of the unit?
Neil: Yes.
Katie: We may also be able to fit in between Mark 2 and 3 or wherever you would like us to for when you are delivering the Unit 5. We can tailor the programme to where they are.
Neil: As I said it would be great to have you come along to the consortium meeting this coming month.

Appendix I: Interview with Lazerath Fiberesima from Walworth Academy

Interviewee: Lazerath Fiberesima, Head of Engineering Diploma Teacher.
Location: Walworth Academy, London, UK
Date: 1st April, 2009

Jen gave background about our project and sponsor.
Lazerath: So the aspect of the Diploma that you are talking about is employing engagement. As you are aware, the Diploma requires 50% applied learning. The applied learning objective has been really hard to deliver because it is hard engaging employers to get involved in the Diploma, the reasons being lack of insurance and cost. To take pupils to a site you need people who are normally working off their jobs to take the students around and production stops. Big companies have educational departments put in place to give something back to the community, and they have chosen to do that through the Diplomas
He goes on to explain the Diplomas levels and skills
Personal Thinking and Learning skills (PTL) need to be incorporated into these levels and units.
He then did a breakdown of a worksheet that he uses with employers.
The design aspect is very important for engineers. They need to look at the armoury and think about why it was made that way at that certain time. They need to think about the materials that were available then. The students around here are exposed to electronics and IT. They can relate to that type of material.
We have one female in our Diploma programme. So you need to think of a programme that is going to be interesting to all students.
Katie: We can provide a session that offers practical application of the material you will deliver in the lectures from certain units.
So you have a workshop available for the students?
Lazerath: Not yet. It is in the process of being built, and hopefully it will be finished in a year or so.
Katie: Our plan is to have the students go through a couple lectures about the background information before attending a session, and then we could provide a couple follow-up exercises.
So when the Diploma was introduced, was your school told that they needed to teach it?
Eustice: Basically the Diploma is covered by Lazerath. He has a Civil Engineering Degree. I came in for technical support.
Lazerath: The government had a great idea of the Diplomas. From then on we were stuck with it. We had a DT department but never an engineering department.
The reason why we can't get girls interested is that students think engineering is messy, you can't wear a suit in engineering, you can't look good in engineering, you have to be muscular/ butch and you're dumb if you are an engineer.
People have the wrong ideas about engineering. They have those misconceptions.
Plumbing is not engineering, being an electrician is not engineering, being a mechanic is not engineering. You don't have to make something; you can sit in an office and design and have people do.
When students opt to do engineering, their first thought is 'give me a screwdriver and all the stuff… let me make something.' Engineering is more writing than actually doing. It is important to get those misconceptions out of them.

Once that's done they'll have the patience to sit down and research and explore things. They need to realize that not every task ends with making something. You can discover something about it, but you don't have to make it. That's where material testing comes in.

Appendix J: Contact List of Schools Offering the Engineering Diploma On-Site

Name (Page Number in School Directory)	Location	Code	Phone Number	Headmaster
Barking Abbey School (129)	Sandringham Road, Barking	IG11 9AG	020 8270 4100	Mr. M Lloyd
Barking College (470)	Dagenham Road, Romford	RM7 0XU	017 0877 0000	Mr. E R Parker
Bishops Justus CofE School (148)	Magpie Hall Lane, Bromley	BR2 8HZ	020 8315 8130	Mrs. K Griffiths
Brampton Manor School (252)	Roman Road, East Ham, London	E6 3SQ	020 7540 0500	Mr. N Berry
Bullers Wood School (148)	St. Nicolas Lane, Logs Hill, Chislehurst, Kent	BR7 5LJ	020 8467 2280	Ms K Clarke
Cator Park School for Girls (148)	Lennard Road, Beckenham, Kent	BR3 1QR	020 8778 5917	Mrs. M Davies
Charles Darwin School (148)	Jail Lane, Biggin Hill, Westerham, Kent	TN16 3AU	019 5957 4043	Mr. R C Higgins
Charter School (298)	Red Post Hill, Dulwich, London	SE24 9JH	020 7346 6600	Ms P Bowmaker
Cumberland School (252)	Oban Close, London	E13 8SJ	020 7474 0231	Ms J V Noble
Dagenham Park School (129)	School Road, Dagenham, Essex	RM10 9QH	020 8270 4400	Mr. J Torrie
Eastbrook School (129)	Dagenham Road, Dagenham, Essex	RM10 7UR	020 8270 4567	Mr. S Smith
Eastbury School (129)	Rosslyn Road, Barking	UG11 9UH	020 8270 4000	Mr. N Weller
Eastlea Community School (253)	Exning Road, London	E16 4ND	020 7540 0400	Ms A Palmer
Forest Gate Community School (253)	Forest Street, London	E7 0HR	020 8534 8666	Mrs. M Wheeler
Harlington Community School (211)	Pinkwell Lane, Harlington, Hayes, Middlesex	UB3 1PB	020 8569 1610	Mr. N Sherman
Hayes School (149)	West Common Road, Hayes, Bromley	BR2 7DB	020 8462 2767	Mr. K Osborne
Kelsey Park Sports College (149)	Manor Way, Beckenham, Kent	BR3 3SJ	020 8650 8694	Mr. B Lloyd
Kemnal Technology College (149)	Sevenoaks Way, Sidcup, Kent	DA14 5AA	020 8300 7112	Mr. J Atkins
Kingsford Community School (253)	Kingsford Way, Beckton, London	E6 5JG	020 7476 4700	Ms J Deslandes
Lambeth Academy (225)	Elms Road, London	SW4 9ET	020 7498 5004	Ms P Millichamp
Lambeth College (475)	Clapham Centre, 45 Clapham Common South Side, London	SW4 9BL	020 7501 5010	Mr. I Ashman
Langdon School (253)	Sussex Road, London	E6 2PS	020 8471 2411	Ms V Wisema
Langley Park School for Boys (149)	Hawksbrook Lane, South Eden Park Road, Beckenham, Kent	BR3 3BP	020 8650 9253	Mr. R W Northcott
Langley Park School for Girls (149)	Hawksbrook Lane, South Eden Park Road, Beckenham, Kent	BR3 3BE	020 8663 4199	Miss J E Sage
Lilian Bayliss Technology School (225)	323 Kennington Lane, London	SE11 5QY	020 7091 9500	Mr G Phillips
Lister Community School (253)	St. Mary's Road, Plaistow, London	E13 9AE	020 8471 3311	Mr M Buck
Little Ilford School (253)	Browning Road, Manor Park, London	E12 6ET	020 8478 8024	Ms Y Powell
London Nautical School (225)	61 Stamford Street, London	SE1 9NA	020 7928 6801	Mr G Wilson
Mellow Lane School (211)	Hewens Road, Hayes End, Hayes, Middlesex	UB4 8JP	020 8573 1039	Mr R Stafford
Newham College of Further Education (476)	Eas Ham Campus, High Street South, London	E6 6ER	020 8257 4000	Mr M Tolhurst
Newham Sixth Form College (453)	Prince Regent Lane, London	E13 8SG	020 7473 4110	Mr S Hughes
Newstead Wood School for Girls (149)	Avebury Road, Orpington, Kent	BR6 9SA	016 8985 3626	Mrs E Allen
Northwood School (211)	Potter Street, Northwood, Middlesex	HA6 1QG	019 2383 6363	Mrs C Ketley
Queensmead School (212)	Queens Walk, South Ruislip, Ruislip, Middlesex	HA4 0LS	020 8845 6266	Mr N McLaughlin
Robert Clack School (129)	Gosfield Road, Dagenham, Essex	RM8 1JU	020 8270 4186	Mr P Grant
Rokeby School (253)	Pitchford Street, London	E15 4RZ	020 8534 8946	Mr M Keary

Southwark College (477)	Bermondsey Centre, Keetons Road, London	SE16 4EE	020 7815 1500	Ms D M Jones
St Angela's RC School (253)	St. George's Road, Forest Gate, London	E7 8HU	020 8472 6022	Mrs D A Smith
St Bonaventure's RC School (253)	Boleyn Road, Forest Gate, London	E7 9QD	020 8472 3844	Mr S Foster
St Saviour's and St Olaves Cof E School (299)	New Kent Road, London	SE1 4AN	020 7407 1843	Mrs. I Bishop
Stockley Academy (212)	Apple Tree Avenue, Yiewsley, West Drayton	UB7 8DA	018 9543 0066	Mr. F Groom
Stockwell Park School (226)	Clapham Road, London	SW9 0AL	020 7733 6156	Ms J Tapper
Stratford School (253)	Upton Lane, Forest Gate, London	E7 9PR	020 8471 2415	Mr. A Seager
Sydney Russell School (129)	Parsloes Avenue, Dagenham, Essex	RM9 5QT	020 8270 4333	Mr. R Leighton
The Douay Martyrs RC School (211)	Edinburgh Drive, Ickenham, Uxbridge	UB10 8QY	018 9567 9400	Mrs. G Davies
The Priory School (149)	Tintagel Road, Orpington, Kent	BR5 4LG	016 8981 9219	Mr. N Ware
The Ravensbourne School (149)	Hayes Lane, Bromley	BR2 9EH	020 8460 0083	MR P Murphy
The Royal Docks Community School (253)	Prince Regents Lane, Custom House, London	E16 3HS	020 7540 2700	Ms P Bagshaw
Uxbridge College (212)	The Greenway, Uxbridge	UB8 2PR	018 9523 4060	Mr. P Lang
Vyners School (212)	Warren Road, Ickenham, Uxbridge	UB10 8AB	018 9523 4342	Mr. B Houghton
Walworth School (299)	Shorncliffe Road, London	SE1 5UJ	020 7450 9570	Ms E Hanham
Warren School (129)	Whalebone Lane North, Chadwell Heath, Romford	RM6 6SB	020 8270 4500	Mrs. B Lloyd

Appendix K: Contact Information for Four Teachers Interviewed in London

Marian Watson	Lead Practitioner for the Engineering Diploma Lambeth Academy Phone: 020 7498 5004 Email: marian.watson@Lambeth-Academy.org
Pete Williamson	Engineering Diploma Teacher Warren School Email: p.williamson@warren.bardaglea.sch.uk
Neil Dickson	Engineering Diploma Teacher Lambeth College Phone: 020 7501 5010 Email: ndickson@LambethCollege.ac.uk
Lazerath Fiberesima	Head of Engineering Diploma Teacher Walworth Academy Phone: 020 7450 9570 Email: lfiberesima@Walworthacademy.org

Appendix L: Learning Outcomes – AQA

AQA – City & Guilds: Learning Outcomes - Principal Learning in Engineering Diploma

Extracted from: Level 1, level 2, level 3 Principal Learning Specifications
http://www.diplomainfo.org.uk/documents/CG_ENG_L1_10pt_v6_WR.pdf
http://www.diplomainfo.org.uk/documents/CG_ENG_L2_10pt_v3_WR.pdf
http://www.diplomainfo.org.uk/documents/CG_ENG_L3_10pt_v3_WR.pdf

Level 1:

Unit 1: Introducing the world of engineering (ENG1U1)

1. know about the different sectors within the Engineering industry, and the types of jobs available in the industry.
2. understand the contribution of engineering to the social and economic development of our world.
3. understand how environmental and sustainability issues, and legislation, affect the operation of the Engineering industry.

Unit 2: Practical engineering and communication skills (ENG1U2)

1. be able to produce and interpret simple engineering drawings and sketches.
2. be able to select and use tools and equipment to measure and mark out, and perform cutting, forming and joining processes.
3. know how to apply Health and Safety standards when organising a safe working area for practical engineering activities.

Unit 3: Using Computer Aided Engineering (ENG1U3)

1. understand how Computer Aided Engineering integrates the design and manufacture of products.
2. be able to use a Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) system.

Unit 4: Routine maintenance operations (ENG1U4)

1. be able to interpret and use technical terms, measurements and data relating to routine engineering maintenance procedures.

2. understand the hazards and risks associated with maintenance, and be able to work responsibly and report Health and Safety issues.
3. be able to select and use appropriate engineering tools, equipment and materials used to carry out.
4. routine maintenance procedures.
5. 4 know how to complete documents and records for procedure undertaken.

Unit 5: Introduction to engineering materials (ENG1U5)

1. know and be able to recognise the types and basic properties of engineering materials.
2. be able to use simple test equipment and basic test procedures to identify materials and evaluatetheir properties.
3. be able to select suitable materials and forming processes for manufacturing particular products.

Unit 6: Introduction to electronics (ENG1U6)

1. understand circuit diagrams and select components.
2. be able to model, prototype and test circuits using Computer Aided Design (CAD) and prototyping systems.
3. be able to build and test electronic circuits, using hand tools and test equipment safely and effectively.

Unit 7: Engineering the future (ENG1U7)

1. know about developments in new materials and engineering technology.
2. understand the environmental issues that relate to engineering including recycling and the disposal of products at the end of their useful life.

Level 2

Unit 1: The engineered world (ENG2U1)

1. know about sectors that make up the Engineering industry, and their products and services.

2. know about the career and training opportunities, job roles, career paths and the role of professional bodies in engineering.
3. understand the purpose of employment legislation.
4. understand the contribution of 19th, 20th and 21st century engineering achievements.

Unit 2: Engineering design (ENG2U2)

1. be able to plan and produce a product design specification from a design brief.
2. be able to produce engineering drawings to meet a product design specification.
3. be able to present engineering designs using drawing standards and conventions.

Unit 3: Engineering applications of computers (ENG2U3)

1. understand the use and advantages of Computer Aided Engineering systems for different activities.
2. be able to plan, prepare, demonstrate and record the use of computers in a range of engineering applications.

Unit 4: Producing engineering solutions (ENG2U4)

1. be able to plan and prepare engineering solutions.
2. be able to use tools and equipment, and select parts, materials and components to achieve the solutions.
3. know the Health and Safety and quality standards, and be able to apply them in the context of the process required for the solutions.

Unit 5: Construct electronic and electrical systems (ENG2U5)

1. be able to select and use electronic and electrical components and sub-systems.
2. be able to construct electronic and electrical systems.
3. be able to test and fault-find electronic and electrical systems.

Unit 6: Manufacturing engineering (ENG2U6)

1. be able to plan and prepare for the production of multiple components.
2. be able to perform manufacturing processes.

3. know about Health and Safety and quality standards, and be able to apply them to manufacturing processes.

Unit 7: Maintenance (ENG2U7)

1. be able to describe and evaluate the operation of a simple maintenance system.
2. be able to complete and record maintenance procedures.

Unit 8: Innovation, enterprise and technological advance (ENG2U8)

1. know about innovation and the impact of technology.
2. understand design, research and development.
3. understand enterprise in the world of engineering.

Level 3

Unit 1: Engineering business and the environment (ENG3U1)

1. understand background information on engineering company profiles.
2. know about the role of project management, and the link between risk analysis and the requirements of current legislation.
3. understand environmental issues relevant to the Engineering industry.

Unit 2: Applications of Computer Aided Designing (ENG3U2)

1. be able to design, model and test engineering products.
2. be able to use 2D and 3D CAD software to produce drawings and models.

Unit 3: Selection and application of engineering materials (ENG3U3)

1. understand engineering specifications and be able to plan safe investigations and testing operations.
2. know how to use tools, equipment, engineering materials and components to conduct testing techniques on a range of materials.
3. be able to gather, record and analyse engineering material information.

Unit 4: Instrumentation and control engineering (ENG3U4)

1. be able to specify engineering control systems.

2. be able to design and implement engineering control systems.

Unit 5: Maintaining engineering systems and products (ENG3U5)

1. be able to manage and organise maintenance operations for engineering systems and products.
2. know how to conduct maintenance procedures for engineering systems and products.

Unit 6: Production and manufacturing (ENG3U6)

1. know the types, uses and importance of engineering manufacturing systems.
2. understand quality control and quality assurance within the Engineering sector.
3. know about and be able to carry out engineering production planning.

Unit 7: Innovative design and enterprise (ENG3U7)

1. be able to analyse engineering innovation and new technologies.
2. understand engineering opportunities, commercial issues, and how to protect new ideas.
3. be able to develop engineering ideas, demonstrating design skills whilst recognising constraints.
4. know how to evaluate environmental issues in relation to engineering designs.

Unit 8: Mathematical techniques and applications for engineers (ENG3U8)

1. be able to apply mathematics and mathematical modeling to solve engineering problems.
2. know how to use trigonometry and co-ordinate geometry to solve engineering problems.
3. know how to use algebra to solve engineering problems.
4. know how to use statistics to solve engineering problems.
5. know how to use calculus to solve engineering problems.

Unit 9: Scientific principles and applications for engineers (ENG3U9)

1. be able to apply scientific knowledge to real engineering systems.
2. be able to demonstrate analytical and problem-solving skills in engineering.
3. know how to use mathematical methods to solve engineering problems.
4. know how to use IT to solve engineering science problems.

5. be able to construct engineering science experiments and record data.

Appendix M: Learning Outcomes – EDEXCEL

EDEXCEL: Learning Outcomes - Principal Learning in Engineering Diploma

Extract from: Guidance and units – EDEXCEL Diplomas Levels 1-3 in Engineering Principal Learning – Issue 1 – June 2008
http://www.edexcel.com/migrationdocuments/Diploma/Dip_Engineering_Specification.pdf

Level 1

Unit 1: Introducing the Engineering World

1. Know about different engineering sectors and employment opportunities.
2. Know about presentation methods, the benefits of working in a team, and the contribution engineering makes to the world we live in.
3. Know how environmental factors influence the engineering world.

Unit 2: Practical Engineering and Communication Skills

1. Understand own responsibilities and those of their colleagues under health and safety legislation.
2. Know about the cutting, forming and joining processes used when producing engineered products.
3. Be able to disassemble and assemble engineered products.
4. Be able to produce sketches of an engineered product or assembly.
5. Be able to plan and produce an engineering product.

Unit 3: Introduction to Computer Aided Engineering

1. Be able to use a CAD system to produce a working drawing of a 2D component and an electrical circuit.
2. Be able to use a CAM system to convert the drawing data into a computer numerically controlled (CNC) operating programme.
3. Be able to set and safely operate a CNC machine tool to produce an accurately machined component and check their own production.

Unit 4: Developing Routine Maintenance Skills

1. Know about different types of maintenance procedures and supporting documentation used in industry.
2. Be able to use tools safely and effectively to carry out a routine maintenance task.
3. Be able to assess a product, piece of equipment or system against causes of failure.

Unit 5: Introduction to Engineering Materials

1. Know about the properties that are used to describe the performance of engineering materials.
2. Know about the materials that engineers use and their forming processes.
3. Be able to identify engineering materials and carry out tests to evaluate their properties.

Unit 6: Electronic Circuit Construction and Testing

1. Know how electronic components are identified.
2. Be able to use symbols to produce an electronic circuit diagram.
3. Be able to work in a team to plan the construction of an electronic circuit from a circuit diagram and then individually build the circuit.
4. Be able to test an electronic circuit.

Unit 7: Engineering the Future

1. Know about the new developments in materials and engineering technology that impact on everyday life.
2. Know how products are recycled or safely disposed of at the end of their useful life.
3. Be able to identify renewable energy sources and the environmental issues of each one.

Level 2

Unit 1: Exploring the Engineering World

1. Know about engineering sectors and their products or services.
2. Know about job opportunities available within the engineering industry and the role of professional engineering institutions.
3. Know about the achievements in engineering that relate to social and economic development.

4. Understand the rights and responsibilities of employers and employees in engineering.

Unit 2: Investigating Engineering Design

1. Know about the construction and function of an engineered product or system
2. Be able to prepare a product design specification
3. Be able to prepare initial design proposals
4. Be able to prepare and submit a final design solution.

Unit 3: Engineering Applications of Computers

1. Know about computer applications in process control and manufacturing.
2. Be able to use computer-based systems to solve an engineering problem.
3. Understand microprocessor control applications in everyday consumer products.
4. Know about computer aided technology in maintenance operations.

Unit 4: Producing Engineering Solutions

1. Understand health and safety procedures, standards and risk assessment in engineering activities.
2. Be able to plan for an engineering product or service.
3. Be able to select suitable materials, parts or components for an engineered product or service.
4. Be able to use processes, tools and equipment to make an engineered product or carry out a service.
5. Be able to apply inspection techniques to the engineered product or service.

Unit 5: Electrical and Electronic Circuits and Systems

1. Understand safe working practices in the workshop/ laboratory and understand relevant electrical and electronic principles.
2. Be able to recognise and select components used in electrical and electronic circuits.
3. Be able to construct an electronic circuit and understand its basic operating principles.
4. Be able to test and find faults on electronic circuits.

Unit 6: Application of Manufacturing Techniques in Engineering

1. Be able to work effectively in a production team and reflect on their performance
2. Know about production information and how this is used to plan and schedule for manufacturing
3. Be able to set up and use tools and CNC equipment safely to process materials
4. Be able to apply appropriate quality control techniques and interpret quality data.

Unit 7: Applications of Maintenance Techniques in Engineering

1. Understand different types of maintenance for engineered products, plant or equipment including the use of statistical trends.
2. Be able to carry out routine maintenance tasks and devise a maintenance procedure.
3. Understand the effects of poor maintenance and the range of spares and replacement parts.
4. Be able to carry out a risk assessment in a maintenance environment.

Unit 8: Exploring Engineering Innovation, Enterprise and Technological Advancements

1. Know about the intellectual property within engineering.
2. Understand the role of research, development and raising finance when designing engineering products.
3. Know about developments in materials and processes on products.
4. Know about the effects of engineering technologies in the home, workplace or built environment.
5. Know about the environmental and social impact of engineering and sustainability of resources.

Level 3

Unit 1: Investigating Engineering Business and the Environment

1. Know how an engineering business is structured and how it operates.
2. Know about internal and external factors that affect the way in which an engineering business operates.
3. Know about and apply financial and planning concepts, and costing and planning techniques.

4. Know the importance of legislation concerning health and safety including a risk assessment for an engineering activity.

Unit 2: Applications of Computer Aided Designing

1. Know about computer systems and methods of data storage.
2. Know about the capabilities of design, presentation, testing and analysis software packages and how they are used as tools within engineering.
3. Be able to use a CAD package to produce 2D drawings.
4. Be able to use design software to produce 3D models for use as presentation drawings or as data for other software uses.
5. Be able to use testing and analysis simulation software as a design support tool.

Unit 3: Selection and Application of Engineering Materials

1. Know about the structure and their effects on the mechanical properties of engineering materials.
2. Know about the forms of supply, applications and the selection of engineering materials.
3. Know about the impact of processing on the structure of engineering materials.
4. Know about the effects of loading, modes of failure and carry out testing of engineering materials.

Unit 4: Instrumentation and Control Engineering

1. Understand the difference between analogue and digital signals and the need for various forms of transmission media
2. Know about the use of sensors, transducers and instrumentation displays in instrumentation and control applications
3. Understand the principles and difference between open loop and closed loop systems
4. Understand the use of programmemable logic controllers in instrumentation and control applications
5. Understand applications of control engineering.

Unit 5: Maintaining Engineering Plant, Equipment and Systems

1. Know about the cost of maintenance and the consequences of plant, equipment or system failure including the effects on production.
2. Be able to deploy effective maintenance strategies when planning a maintenance activity.
3. Know how the data gathered from monitoring the performance and condition of engineering plant, equipment or system can be used.
4. Be able to carry out a risk assessment and follow a maintenance plan using documentation for a maintenance activity on a closed loop engineering system.

Unit 6: Investigating Modern Manufacturing Techniques used in Engineering

1. Understand the differences between traditional and modern manufacturing production systems used within engineering industries.
2. Understand how different types of manufacturing processes utilise computer aided manufacturing systems.
3. Be able to plan for the production of an engineered product for industry.
4. Be able to work in a team and apply quality control and quality assurance systems.

Unit 7: Innovative Design and Enterprise

1. Know how a successful new product evolves.
2. Know about individuals who have become successful engineering entrepreneurs.
3. Understand how engineering activities impact on society and the environment.
4. Be able to produce or improve designs in an innovative way.
5. Know about opportunities for success when bringing a new product to market.

Unit 8: Mathematical Techniques and Applications for Engineers

1. Know how to use algebraic methods to solve engineering problems.
2. Be able to use trigonometric methods to solve engineering problems.
3. Be able to use statistical methods to display engineering data.
4. Know how to apply elementary calculus techniques to solve engineering problems.

Unit 9: Principles and Application of Engineering Science

1. Be able to apply mechanical principles to determine the effects of forces in engineering systems.
2. Be able to apply mechanical principles to determine the effects of motion, work and energy transfer in engineering systems.
3. Be able to apply electrical principles to determine the effects of electric charge and current and determine the voltage, current, resistance and power in electrical circuits.
4. Be able to apply the principles of heat and thermodynamics to determine the effects of expansion and compression of gases and energy transfer in engineering systems.
5. Know about the principles of chemistry and the effects of chemical processes and reactions.
6. Be able to apply the principles of fluid dynamics to determine the effects of viscosity and the forces acting in hydrostatic systems.

Appendix N: Learning Outcomes - OCR

OCR: Learning Outcomes - Principal Learning in Engineering Diploma

Extracted from: OCR Centre Handbook for Level 1, Level 2, Level 3; Section 3 – Accredited units
http://www.ocr.org.uk/Data/publications/key_documents/Diploma_Engineering_L1_Centre_Handbook_Section_03_Accredited_Units.pdf
http://www.ocr.org.uk/Data/publications/key_documents/Diploma_Engineering_L2_Centre_Handbook_Section_03_Accredited_Units.pdf
http://www.ocr.org.uk/Data/publications/key_documents/Diploma_Engineering_L3_Centre_Handbook_Section_03_Accredited_Units.pdf

Level 1

Unit F541: Introduction to the World of Engineering

1. Understand the contribution of great engineering achievement since the 19th century.
2. Know about different engineering sectors and the employment opportunities.
3. Be able to identify the environmental and human effects of engineering industries and identify ways in which resources can be conserved.

Unit F542: Practical Engineering and Communication Skills

1. Develop a knowledge and understanding of health and safety issues.
2. Develop a knowledge and understanding of the cutting, forming and joining processes used when producing engineered products.
3. Develop a know ledge and understanding of techniques used to assemble and disassemble engineered products. Communicate these to a third party.
4. Develop a knowledge and understanding of drawing techniques used to communicate technical information.

Unit F543: Using Computer Aided Engineering

1. Develop a knowledge and understanding of how computer software packages are used to design and visualize products.
2. Develop a knowledge and understanding of how computer software packages are used to control the operation of machine tools.
3. Develop a knowledge and understanding of how the design and manufacture of products can be integrated under the banner of Computer Aided Engineering.

Unit F544: Routine Maintenance Operations

1. Develop an understanding of the types of maintenance procedures carried out in industry.
2. Develop an understanding of Health and Safety issues relating to the learner and others.
3. Develop an understanding of the documentation used when planning, recording and carrying out maintenance of engineered products and services to a schedule.

Unit F545: Introduction to Engineering Materials

1. Develop an understanding of the basic properties of a range of engineering materials.
2. Develop an understanding of forming processes applicable to particular materials.
3. Develop a knowledge and understanding of how an engineering designer decides which materials to use for a particular engineering application.

Unit F546: Introduction to Electronics

1. Develop an understanding of circuit diagrams.
2. Be able to identify, select and assemble correctly electronic components, materials. Be able to identify, select and use tools needed to construct electronic circuits and understand their uses and application.
3. Develop an understanding of the processes underpinning circuit testing. Be able to test circuits by selecting the appropriate test equipment.

Unit F547: Engineering the Future

1. Independently identify and use appropriate sources of information to gain knowledge and understanding of the importance of the use of new materials and technologies.
2. Independently research and investigate knowledge and understanding of the methods of recycling and safe disposal of products at the end of their useful life.
3. Independently research and investigate knowledge and understanding of sources of renewable energy and associated environmental issues.
4. As part of a team, plan and present a view of 'Engineering the future'.

Level 2

Unit F548: The Engineered World

1. Understand the contribution of great engineering achievements to social and economic development since the 19th century.

2. Know about the sectors of engineering, their products, services and the role of professional bodies and sector skills councils.
3. Know about job roles in engineering, career and training opportunities and the rights and responsibilities of employers and employees.
4. Be able to identify the environmental effects of engineering industries and explain ways in which resources can be conserved.

Unit F549: Engineering Design

1. Develop a knowledge and understanding of the importance of the performance and functions of an engineered product.
2. Develop a knowledge and understanding of the implications of standards, legislation.
3. Be able to develop knowledge and understanding of the key considerations influencing product design specifications.
4. Develop knowledge and understanding of a range of techniques used in producing and presenting design ideas and solutions.
5. Develop a knowledge and understanding of proving (testing the design in the environment in which the design will function) a design involving an appreciation of scientific, mathematical and materials issues that underpin designing.

Unit F550: Engineering Applications of Computers

1. Develop knowledge and understanding of the way computers are used in engineering, manufacturing and process control.
2. Develop knowledge and understanding of simple control programmes
3. Develop knowledge and understanding of simple expert systems for problem solving and maintenance operations in engineering.
4. Develop knowledge and understanding of computer-based communication systems to communicate data.

Unit F551: Producing Engineering Solutions

1. Be able to interpret and use engineering drawings. Be able to select suitable materials and standard components for engineering applications. Develop knowledge and understanding of planning. Understand the need for health and safety standards.

2. Be able to demonstrate that they have used tools, equipment and processes to create a high-quality and accurate outcome.
3. Be able to perform quality control checks.

Unit F552: Construct electronic and electrical systems

1. Demonstrate knowledge and understanding of basic electronic and electric principles and associated safe working practices.
2. Demonstrate knowledge and understanding of the operating principles of a range of electronic and electrical components.
3. Demonstrate knowledge and understanding of the construction of electronic and electrical circuits.
4. Demonstrate knowledge and understanding of testing and evaluation of the operation of electronic and electrical circuits.

Unit F553: Manufacturing Engineering

As part of a team the learner will demonstrate knowledge and understanding of:

1.1 The importance of planning for manufacture of the prescribed product and the consideration of alternative methods.

1.2 The need to co-operate with others and share responsibilities for the success of the manufacture of multiple components.

Individually the learner will demonstrate knowledge and understanding of:

2 The types and importance of a variety of quality checks and the use of statistical methods of testing.

3 Programming and setting up a CNC machining operation; The health and safety risks associated with the machining process.

Unit F554: Maintenance

1 The learner will develop knowledge and understanding of the procedures used in maintaining an engineered product or system.

2 The learner will develop knowledge and understanding of the implications for the user and the manufacturer if engineered products or systems are not properly maintained.

3 The learner will develop knowledge and understanding about different causes for the failure of engineered products and systems, and the use of statistical methods in measuring and analyzing failure trends.

Unit F555: Innovation, enterprise and technological advance
The learner will demonstrate knowledge and understanding of:

1 How innovation and creativity benefit engineering.
2 How ideas and new developments are protected.
3 The roles of research, development and raising finance when developing new products.
4 The impact of new developments in materials and processes on products. The effects of the engineering technologies in the home, workplace and built environment.
5 The environmental and social impact of engineering and sustainability of resources.

Level 3

Unit 556: Engineering Business and the Environment

1 Gain knowledge and understanding of businesses within a specific engineering sector. They will examine the organisation of engineering businesses and the influence of external and internal factors, which include: career pathways, employee and the business registration and regulation, contractual arrangements, legislative requirements, and the importance and function of risk assessment.
2 Develop knowledge and understanding of the role of project management.
3 Develop knowledge and understanding of clean manufacturing, including the management of resource depletion, the sources of environmental pollution and the engineering methods used to control them.
4 Develop knowledge and understanding of the management of changes in the environment, methods of land management and water supply and the associated solutions.
5 Undertake research activities, collection and mathematical analysis of environmental sample, data collection and analysis and simple chemical analysis.

Unit F557: Applications of Computer Aided Designing

1 Acquire knowledge and develop understanding of the use of 2D and 3D software.
2 Acquire knowledge and develop understanding of drawing to industrial standards.
3 Acquire knowledge and develop understanding of techniques for modifying presentation drawings.

4 Acquire knowledge and develop understanding of designing for manufacture.
5 Acquire knowledge and develop understanding of the integration of CAD/CAM into combined design/manufacturing systems.
6 Acquire knowledge and develop understanding of the use of concurrent engineering systems.

Unit F558: Selection and Application of Engineering Materials
The learner will develop knowledge and understanding of:

1 Atomic structures, amount of bonding, periodicity and classification of engineering materials.
2 Mechanical and thermal properties and durability of materials; destructive and non-destructive testing methods.
3 Effects of processing on structure and behaviour of materials.
4 Factors of safety and modes of failure of engineering materials.
5 Using information sources to select materials for engineering applications and research the standard forms in which materials are supplied.
6 Key features of new and smart materials and their potential applications.

Unit F559: Instrumentation and Control Engineering

1 Develop knowledge and understanding of the systems approach to control engineering.
2 Develop knowledge and understanding of open loop, close loop, feed forward and feedback control theory.
3 Develop knowledge and understanding of data communications and multiplexers.
4 Develop knowledge and understanding of AD/DA controllers and PLCs.
5 Develop knowledge and understanding of signals and Wave Guides.
6 Develop knowledge and understanding of Actuators and Instrumentation Displays.
7 Develop knowledge and understanding of industrial and commercial applications of control engineering.
8 Develop knowledge and understanding of simulation software.

Unit F560: Maintaining Engineering Systems
The Learner will:

1 Understand the use of statistical methods in engineering maintenance.

2 Understand failure modes of engineering systems.

3 Understand the importance of appropriate maintenance strategies.

Unit F561: Production and manufacturing
The learner will develop knowledge and understanding of:

1 Different types of manufacturing processes and systems.

2 Assembly systems and techniques.

3 Quality control and quality assurance requirements in manufacturing and production, including statistical process control.

4 Production planning considerations.

5 Project planning and scheduling, communication and computer skills.

Unit F562: Innovative Design and Enterprise
The learner will understand:

1 Why engineered products are successful and are able to relate their understanding to an engineering entrepreneur and associated product.

2 What is meant by entrepreneurship, particularly in engineering and the relationship to innovative designs and new technologies.

3 The principles of developing, marketing and selling a new product or idea.

4 The environmental and social impact of engineering locally and globally.

5 What is meant by sustainable engineering.

Unit F563: Mathematical Techniques and Applications for Engineers
The learner will develop knowledge and understand:

1 Algebra

Algebraic brackets
Binomial expressions
Algebraic factorization
Algebraic equations
Simultaneous equations
Transposition of formulae
Transposition of formulae containing a square root or power
Transposition of formulae containing two like terms
Quadratic equations – solution by

(a) factorisation
(b) completing the square
(c) formula
Partial fractions

2 Geometry and trigonometry

Degree and radians
Length of arc of a circle
Area of sector of a circle
Solution of a right-angled triangle
Graphs of trigonometrical functions $y = \sin x$, $y = \cos x$ and $y = \tan x$
Values of sin x, cos x and tan x for angles between 00 and 3600
Sine rule
Cosine rule
Area of a triangle
Complementary angles
Ratios of 300, 450 and 600
Reciprocal of sine, cosine and tangent
Trigonometrical identities
Solid trigonometry with three-dimensional problems

3 Calculus

The gradient of a curve
Differentiation of algebraic functions
Maximum and minimum turning points
Differentiation of sine and cosine
Differentiation of the exponential function
Differentiation of the logarithmic function
Indefinite integrals
Definite integrals
Area under a curve
Integrals of sin x and cos x

4 Statistics

Data Handling
Histograms
Frequency polygon
Cumulative frequency
Arithmetic mean, mode and median
Percentiles and quartiles
Distribution curves
Standard deviation
Probability

Expectation
Dependent events without replacement
Independent events with replacement
Addition law of probability
Multiplication law of probability

Unit F564: Scientific Principles and Applications for Engineers
The learner will acquire knowledge and understand:

1 Force and Motion
2 Kinematics
3 Dynamics
4 Force, Work and Power.
5 Deformation of Solids
6 Electricity
7 Quantum Physics
8 Electromagnetic Waves
9 Waves
10 Gravitational Fields
11 Electric Fields
12 Capacitors
13 Electromagnetism
14 Electromagnetic Induction
15 Thermal Physics
16 Nuclear Atom and Radioactivity
17 Properties of Materials
18 Electronics
19 Chemical reactions
20 Organic compounds and functional groups
21 Health and Safety

Appendix O: The Royal Armouries Current Teacher Feedback Form

Date of Visit:
School:
Teacher:
Age Group;
Session:
Has your school: visited the Tower before? had a taught session before? had a Science session before?

Please rate today's session according to the following criteria:

1 = Strongly Disagree 2 = Disagree 3 = Agree 4 = Strongly Agree

The presenter was fully prepared	**1**	**2**	**3**	**4**
The session objectives were clear	**1**	**2**	**3**	**4**
Activities were appropriate to the pupil's capability and needs	**1**	**2**	**3**	**4**
Pupils were encouraged to use their imagination and to think creatively	**1**	**2**	**3**	**4**

Was the session as you anticipated? If not what was different?
How do you think your group has benefited from today's session?
Do you have any suggestions for improvements for this session?

Do you have any suggestions for future sessions:
Do you follow Q.C.A schemes of work? Was the Science session relevant to your curriculum? If not why not/how could this be improved
Would you come back to do this session again? Would you come to any of our other sessions? If so please state what type of sessions you would be interested in.
Any other comments:

Overall rating: (1 = poor, 2 = satisfactory, 3 = good, 4 = excellent)	**1**	**2**	**3**	**4**

Please either:

- Return this evaluation to the session leader
- Fax it to: 0203 166 6678
- Post it to: Amy Preece and Elena Kallas
  Lanthorn Tower, H.M Tower of London, London
  EC3N 4AB.

Bayer MaterialScience

ROYAL ARMOURIES

Appendix P: Proposed Teacher Feedback Form

Date of Visit:		School:	
Teacher:		Age Group:	
Session:			
Has your school visited the Tower before?			
Has your school had a taught session before?			
Has your school had a Engineering Diploma session before?			

How well this sessions match the Engineering Diploma curriculum (General format)			
Relevant Learning Outcomes and description	Not covered	Adequately covered	Covered beyond expectation
Unit #LO#: Description			
Unit #LO#: Description			
Unit #LO#: Description			
Unit #LO#: Description			

For the Learning Outcomes that were NOT met, what is the reason?
What do you particularly LIKE about the session?
What do you particularly DISLIKE about the session?
Would you come back to do the same session again?

My overall rating:			
1. Poor	2. Satisfactory	3. Good	4. Excellent
Other Comments & Suggestions:			
By completing and sending back this form, you will get 5 students free of charge for your next booking. Thank you!			
Please either: • Return this evaluation to the session leader • Fax it to: 0203 166 6678 • Post it to: Amy Preece and Elena Kallas Lanthorn Tower, H.M Tower of London, London EC3N 4AB.			

Bayer MaterialScience

ROYAL ARMOURIES

Appendix Q: Proposed Students Feedback Form

School: _____ Session: _____

Today I:	Very much	Neutral	Not at All
Had fun with the Material			
Was excited about engineering			
Learned something new			
Thought the presenter did a good job teaching			
Did your lessons at school prepare you for this session?			

Appendix R: Current Session Modification

Educational Session	Exam. Board	Levels	Current Learning Outcomes Links
How Strong is your Material?	AQA	Level 1	U5LO1; U5LO2; U5LO3
		Level 2	U4LO2;
		Level 3	U3LO2; U3LO3; U8LO1; U8LO2; U8LO3; U9LO5; U9LO3; U9LO4
	EDEXCEL	Level 1	U5LO1; U5LO2; U5LO3;
		Level 2	U3LO2;
		Level 3	U3LO4; U8LO1;
	OCR	Level 1	F545LO1;
		Level 2	F550LO1; F550LO3
		Level 3	F558LO2; F563LO1; F564LO17;
Current Topics and Activities		Suggested Modification for the Engineering Diploma	
1. Museum objects handling 2. Tensile strength machine operation 3. Data recording and calculation 4. Comparison and interpretation		1. Background information about tensile strength and other mechanical properties used to describe materials (e.g. Hardness, resilience, toughness, yield strength). 2. Information about historic strength testing methods used for armours. 3. Relate the micro-structure of material to its tensile strength (e.g. Ionic, covalent, metallic boding). 4. Relate material strength to its applications (such as why to use plastic for riot shield) 5. Introduce and test some novel materials (such as QTC and smart metals). 6. Give students some sort of a problem for which they need to determine the most appropriate material through testing and analysis (similar to problem presented in "How Strong is Your Longbow?") could be continued into a mini project by teachers after visiting the RA 7. Speak briefly about the Health and Safety aspects of using the testing equipment, etc.	
Additional Links after Modification	AQA	Level 1	U5LO1(expansion)(M1); U5LO3 (M1,4); U7LO1 (M5); U5LO2(expansion)(M2)
		Level 2	U8LO1 (M5); U2LO1 (M6); U4LO1 (M6); U4LO3 (M7); U8LO2 (M6)
		Level 3	U7LO1 (M5); U3LO1 (M3,4,5,7); U9LO2(M6)
	EDEXCEL	Level 1	U7LO1 (M5);
		Level 2	U4LO3 (M1,3,4, 6); U8LO3 (M5); U4LO1 (M7)
		Level 3	U3LO1 (M3); U3LO2 (M1, 4);
	OCR	Level 1	F545LO3 (M4, M6); F547LO1 (M5); F542LO1 (M7)
		Level 2	F549LO5 (M6); F551LO1 (M6)
		Level 3	F558LO1 (M4); F558LO5 (M6) F558LO6 (M5);

<table>
<tr><td>Educational Session</td><td>Exam. Board</td><td>Levels</td><td>Current Learning Outcomes Links</td></tr>
<tr><td rowspan="9">Plastic - Fantastic?</td><td rowspan="3">AQA</td><td>Level 1</td><td>U5LO1; U5LO2; U5LO3</td></tr>
<tr><td>Level 2</td><td>U4LO2;</td></tr>
<tr><td>Level 3</td><td>U3LO1; U3LO2; U3LO3;</td></tr>
<tr><td rowspan="3">EDEXCEL</td><td>Level 1</td><td>U5LO1; U5LO3;</td></tr>
<tr><td>Level 2</td><td>U4LO3;</td></tr>
<tr><td>Level 3</td><td>U3LO2; U3LO4; U9LO5;</td></tr>
<tr><td rowspan="3">OCR</td><td>Level 1</td><td>F545LO1;</td></tr>
<tr><td>Level 2</td><td></td></tr>
<tr><td>Level 3</td><td>F558LO2; F564LO5; F564LO17; F564LO19;</td></tr>
<tr><td colspan="2">Current Topics and Activities</td><td colspan="2">Suggested Modification for the Engineering Diploma</td></tr>
<tr><td colspan="2">1. Background information presentation
2. Museum objects handling
3. Three hands-on activities
a. Plastics identification by float test.
b. Explore the effect of damaging solvents to plastics.
c. Plastics strength identification.</td><td colspan="2">1. In depth comparison between Metal and Plastic after object handling session (Difference in molecular structure, mechanical properties, application).
2. comparison between ancient (e.g. Norman helmet) and modern design process and manufacturing methods used for the handled objects (e.g. A modern motorcycle helmet was designed using 3D CAD software, then use Finite Element Analysis to do virtual strength testing, use 3D printing for fast prototyping and injection molding for mass production) with power point slides.
3. Use tensile strength machine for experiment 3 in addition to simple testing, Talk about how tensile strength machine works.
4. Experiment 1: Info about molecular structure of 4 types of plastic and how it relates to the density and crease effect as tested in the experiment.</td></tr>
<tr><td rowspan="9">Additional Links after Modification</td><td rowspan="3">AQA</td><td>Level 1</td><td>U3LO1 (M2); U5LO3 (M1,2);</td></tr>
<tr><td>Level 2</td><td>U3LO1 (M2); U3LO2 (M3);</td></tr>
<tr><td>Level 3</td><td>U9LO1 (M3,M4); U8LO1 (M3); U8LO3 (M3); U8LO5 (M3); U9LO3 (M3); U9LO4 (M3); U9LO5 (M3)</td></tr>
<tr><td rowspan="3">EDEXCEL</td><td>Level 1</td><td>U2LO2 (M2); U5LO2 (M2); U7LO1 (M2);</td></tr>
<tr><td>Level 2</td><td>U3LO1 (M2); U3LO2 (M3);</td></tr>
<tr><td>Level 3</td><td>U3LO1 (M1,4);</td></tr>
<tr><td rowspan="3">OCR</td><td>Level 1</td><td>F545LO2 (M2); F545LO3 (M1,2);</td></tr>
<tr><td>Level 2</td><td>F550LO1 (M2,3);</td></tr>
<tr><td>Level 3</td><td>F558LO1 (M1,4); F558LO5 (M1,2);</td></tr>
</table>

Educational Session	Exam. Board	Levels	Current Learning Outcomes Links
Modern Materials	AQA	Level 1	U5LO1; U5LO2; U5LO3; U7LO1;
		Level 2	U1LO4; U8LO3;
		Level 3	U3LO1; U3LO2; U3LO3; U7LO1
	EDEXCEL	Level 1	U5LO2; U5LO3;
		Level 2	U7LO1; U8LO3; U8LO4;
		Level 3	U3LO2;
	OCR	Level 1	F545LO1; F545LO3; F547LO1;
		Level 2	F555LO1; F555LO4;
		Level 3	F558LO2; F558LO6;
Current Topics and Activities		Suggested Modification for the Engineering Diploma	
1. General background information: alloys, polymers, polymorph, smart metals, smart polymers, smart fluids and Composite. 2. Hands on activities & mini experiments: a. QTC b. Thermo chromatic Polymers (duck, spoon, paper &beads) c. Smart Metals d. Polymorph and Thermoplastics e. Smart Fluids		1. QTC: talk about the entrepreneur success of Peratech behind QTC; talk about quantum tunneling effect; use multimetre and weight to measure force and corresponding resistance and manually plot the Force VS Resistance chart. 2. Thermo chromatic Polymers: explain the molecular mechanism of thermo chromatic phenomenon; information about who and how people discovered this material 3. Smart Metals: Give schematic representations of the crystal structures at different stages and the mechanism of phase transformation caused by heating. 4. Smart fluid: explain the molecular basis of shear thickening fluid and its current development & application.	
Additional Links after Modification	AQA	Level 1	
		Level 2	U8LO3 (M1);
		Level 3	U7LO2 (M1);
	EDEXCEL	Level 1	
		Level 2	U8LO1 (M1);
		Level 3	U3LO1 (2,3,4); U7LO1 (M1); U7LO2 (M1);
	OCR	Level 1	
		Level 2	F555LO3 (M1);
		Level 3	F558 (M2,3,4); F562LO1 (M1);

Educational Session	Exam. Board	Levels	Current Learning Outcomes Links
Sports Science	AQA	Level 1	U5LO1; U5LO2; U5LO3; U7LO1 (object handling)
		Level 2	U4LO2; U4LO1
		Level 3	U7LO3; U7LO1
	EDEXCEL	Level 1	U5LO1; U5LO2; U5LO3;
		Level 2	U2LO4; U4LO3;
		Level 3	U3LO1; U7LO4;
	OCR	Level 1	F545LO1; F545LO3;
		Level 2	F549LO3;
		Level 3	F558LO2; F564LO1; F564LO2; F564LO17;
Current Topics and Activities		Suggested Modification for the Engineering Diploma	
1. Museum Object Handling 2. Discussion of alloys, polymers and Non-Newtonian fluids; compare ancient and modern body protection. 3. Hands-on activities a. Eggstreme Sports b. Staying Cool c. Salol Experiment		1. Expand the depth of discussion following the object handling section and use power point slides. (e.g. Types of mechanical joints and those used on armour, comparison about molecular structure and mechanical properties between metal and plastic, etc) 2. Eggstreme sports: introduce the concept of impact force: m*g*h= ½*m*V^2=F*L which means if other things equal, the longer the cushioned distance, the smaller the impact force thus less damage. 3. Staying cool: Introduce 3 laws of thermodynamics and different means of heat transfer (conduction, convection & radiation) and how these rules apply to this experiment (e.g. As the ice is melting, the temperature of the system tends to go to equilibrium) 4. Let one student from each table give a presentation about findings.	
Additional Links after Modification	AQA	Level 1	
		Level 2	
		Level 3	U8LO1 (M2); U8LO3 (M2); U9LO1 (M1,2,3); U3LO2 (M1); U9LO3 (M2)
	EDEXCEL	Level 1	U1LO2 (M4);
		Level 2	
		Level 3	U8LO1 (M2); U9LO1 (M2);U9LO2 (M2,3); U9LO4(M3);
	OCR	Level 1	F542LO3 (M4);
		Level 2	F549LO4 (M4);
		Level 3	F558LO1 (M1); F563LO1(M2); F564LO4(M2); F564LO15(M3);

<table>
<tr><td>Educational Session</td><td>Exam. Board</td><td>Levels</td><td>Current Learning Outcomes Links</td></tr>
<tr><td rowspan="9">Catapults and Trebuchets</td><td rowspan="3">AQA</td><td>Level 1</td><td>U2LO2;</td></tr>
<tr><td>Level 2</td><td>U4LO1; U4LO2;</td></tr>
<tr><td>Level 3</td><td>U9LO2;</td></tr>
<tr><td rowspan="3">EDEXCEL</td><td>Level 1</td><td>U2LO3;</td></tr>
<tr><td>Level 2</td><td>U1LO3; U4LO3;</td></tr>
<tr><td>Level 3</td><td></td></tr>
<tr><td rowspan="3">OCR</td><td>Level 1</td><td>F542LO3;</td></tr>
<tr><td>Level 2</td><td>F551LO2;</td></tr>
<tr><td>Level 3</td><td>F564LO1; F564LO10;</td></tr>
<tr><td colspan="2">Current Topics and Activities</td><td colspan="2">Suggested Modification for the Engineering Diploma</td></tr>
<tr><td colspan="2">1. Background info about ancient war machines
2. Discussion about how Catapults and Trebuchets work.
3. Predict the effect of the length of the spoon and the weight of the marble on the throw.
4. Model building and testing.</td><td colspan="2">1. Introduce the concept of energy conservation and transfer for a Trebuchet, Introduce the related mathematical equation: m (weight)*g*Δh(weight) – m(ball)*g*Δh(ball) = ½ *m(ball)*V^2 (velocity of the weight and arm is ignored, in this case, energy is transferred from the gravitational potential of the weight to the gravitational potential and velocity of the ball and the overall mechanical energy is conserved through this process).
2. Use this equation to do the prediction (e.g. Derive the expression for V in terms of other variables which gives a reverse relationship between V and m(ball) which means the heavier the marble, the shorter the throw)
3. Let several students give a presentation about the result and findings.
4. Allow students to choose materials and build their own catapults and trebuchets using pictures and diagrams as a guide</td></tr>
<tr><td rowspan="9">Additional Links after Modification</td><td rowspan="3">AQA</td><td>Level 1</td><td>U5LO3(M4); U2LO1(M4)</td></tr>
<tr><td>Level 2</td><td>U4LO2 (expansion)</td></tr>
<tr><td>Level 3</td><td>U8LO1 (M1,2); U9LO1 (M1,2); U9LO3 (M1,2); U9LO3 (M1); U7LO3 (M4)</td></tr>
<tr><td rowspan="3">EDEXCEL</td><td>Level 1</td><td>U1LO2 (M3);</td></tr>
<tr><td>Level 2</td><td></td></tr>
<tr><td>Level 3</td><td>U8LO1 (M1,2); U9LO1 (M1,2); U9LO2 (M1,2);</td></tr>
<tr><td rowspan="3">OCR</td><td>Level 1</td><td></td></tr>
<tr><td>Level 2</td><td></td></tr>
<tr><td>Level 3</td><td>F563LO1 (M1,2); F564LO3 (M1,2); F564LO4 (M1,2);</td></tr>
</table>

Appendix S: Ranking Matrices for Session Modification

1. How Strong is Your Material?

EASE OF IMPLEMENTATION				
Modification	Description	Easy	Moderate	Hard
1	Background information about tensile strength and other mechanical properties used to describe materials (e.g. Hardness, resilience, toughness, yield strength)		x	
2	Information about historic strength testing methods used for armours.		x	
3	Relate the micro-structure of material to its tensile strength (e.g. Ionic, covalent, metallic bonding).		x	
4	Relate material strength to its applications (such as why to use plastic for riot shield)	x		
5	Introduce and test some novel materials (such as QTC and smart metals).	x		
6	Give students some sort of a problem for which they need to determine the most appropriate material through testing and analysis (similar to problem presented in “How Strong is Your Longbow?”) could be continued into a mini project by teachers after visiting the RA			x
7	Speak briefly about the Health and Safety aspects of using the testing equipment, etc.	x		

AMOUNT OF MATERIAL COVERED					
Modification	Description	Additional LOs	Small (1-3 LOs)	Medium (4-6 LOs)	Large (7+ LOs)
1	Background information about tensile strength and other mechanical properties used to describe materials (eg. Hardness, resilience, toughness, yield strength)	4		x	
2	Information about historic strength testing methods used for armours.	1	x		
3	Relate the micro-structure of material to its tensile strength (eg. Ionic, covalent, metallic bonding).	3	x		
4	Relate material strength to its applications (such as why to use plastic for riot shield)	5		x	
5	Introduce and test some novel materials (such as QTC and smart metals).	6		x	
6	Give students some sort of a problem for which they need to determine the most appropriate material through testing and analysis (similar to problem presented in “How Strong is Your Longbow?”) could be continued into a mini project by teachers after visiting the RA	9			x
7	Speak briefly about the Health and Safety aspects of using the testing equipment, etc.	4		x	

2. Plastic – Fantastic?

EASE OF IMPLEMENTATION				
Modification	Description	Easy	Moderate	Hard
1	In depth comparison between Metal and Plastic after object handling session (Difference in molecular structure, mechanical properties, application).	x		
2	comparison between ancient (eg. norman helmet) and modern design process and manufacturing methods used for the handled objects (eg. A modern motorcycle helmet was designed using 3D CAD software, then use Finite Element Analysis to do virtual strength testing, use 3D printing for fast prototyping and injection molding for mass production) with power point slides.		x	
3	Use tensile strength machine for experiment 3 in addition to simple testing, Talk about how tensile strength machine works.	x		
4	Experiment 1: Info about molecular structure of 4 types of plastic and how it relates to the density and crease effect as tested in the experiment.		x	

AMOUNT OF MATERIAL COVERED					
Modification	Description	Additional LOs	Small (1-3 LOs)	Medium (4-6 LOs)	Large (7+ LOs)
1	In depth comparison between Metal and Plastic after object handling session (Difference in molecular structure, mechanical properties, application).	5		x	
2	comparison between ancient (eg. norman helmet) and modern design process and manufacturing methods used for the handled objects (eg. A modern motorcycle helmet was designed using 3D CAD software, then use Finite Element Analysis to do virtual strength testing, use 3D printing for fast prototyping and injection molding for mass production) with power point slides.	11			x
3	Use tensile strength machine for experiment 3 in addition to simple testing, Talk about how tensile strength machine works.	10			x
4	Experiment 1: Info about molecular structure of 4 types of plastic and how it relates to the density and crease effect as tested in the experiment.	3	x		

3. Modern Materials

EASE OF IMPLEMENTATION				
Modification	Description	Easy	Moderate	Hard
1	QTC: talk about the entrepreneur success of Peratech behind QTC; talk about quantum tunneling effect;	x		
2	Thermo chromatic Polymers: explain the molecular mechanism of thermo chromatic phenomenon; information about who and how people discovered this material		x	
3	Smart Metals: Give schematic representations of the crystal structures at different stages and the mechanism of phase transformation caused by heating		x	
4	Smart fluid: explain the molecular basis of shear thickening fluid and its current development & application.	x		

AMOUNT OF MATERIAL COVERED					
Modification	Description	Additional LOs	Small (1-3 LOs)	Medium (4-6 LOs)	Large (7+ LOs)
1	QTC: talk about the entrepreneur success of Peratech behind QTC; talk about quantum tunneling effect;	7			x
2	Thermo chromatic Polymers: explain the molecular mechanism of thermo chromatic phenomenon; information about who and how people discovered this material	2	x		
3	Smart Metals: Give schematic representations of the crystal structures at different stages and the mechanism of phase transformation caused by heating	2	x		
4	Smart fluid: explain the molecular basis of shear thickening fluid and its current development & application.	2	x		

4. Sports Science

EASE OF IMPLEMENTATION				
Modification	Description	Easy	Moderate	Hard
1	Expand the depth of discussion following the object handling section and use power point slides. (eg. Types of mechanical joints and those used on armour, comparison about molecular structure and mechanical properties between metal and plastic, etc)		x	
2	Eggstreme sports: introduce the concept of impact force: m*g*h= ½*m*V^2=F*L which means if other things equal, the longer the cushioned distance, the smaller the impact force thus less damage.			x
3	Staying cool: Introduce 3 laws of thermodynamics and different means of heat transfer (conduction, convection & radiation) and how these rules apply to this experiment (eg. As the ice is melting, the temperature of the system tends to go to equilibrium)			x
4	Let one student from each table give a presentation about findings.	x		

AMOUNT OF MATERIAL COVERED					
		Additional LOs	Small (1-3 LOs)	Medium (4-6 LOs)	Large (7+ LOs)
1	Expand the depth of discussion following the object handling section and use power point slides. (eg. Types of mechanical joints and those used on armour, comparison about molecular structure and mechanical properties between metal and plastic, etc)	3	x		
2	Eggstreme sports: introduce the concept of impact force: m*g*h= ½*m*V^2=F*L which means if other things equal, the longer the cushioned distance, the smaller the impact force thus less damage.	8			x
3	Staying cool: Introduce 3 laws of thermodynamics and different means of heat transfer (conduction, convection & radiation) and how these rules apply to this experiment (eg. As the ice is melting, the temperature of the system tends to go to equilibrium)	4		x	
4	Let one student from each table give a presentation about findings.	3	x		

5. Catapults and Trebuchets

EASE OF IMPLEMENTATION				
Modification	Description	Easy	Moderate	Hard
1	Introduce the concept of energy conservation and transfer for a Trebuchet, Introduce the related mathematical equation: m(weight)*g*∆h(weight) – m(ball)*g*∆h(ball) = ½ *m(ball)*V^2 (velocity of the weight and arm is ignored, in this case, energy is transferred from the gravitational potential of the weight to the gravitational potential and velocity of the ball and the overall mechanical energy is conserved through this process).		x	
2	Use this equation to do the prediction (eg. Derive the expression for V in terms of other variables which gives a reverse relationship between V and m(ball) which means the heavier the marble, the shorter the throw)		x	
3	Let several students give a presentation about the result and findings.	x		
4	Allow students to choose materials and build their own catapults and trebuchets using pictures and diagrams as a guide			x

AMOUNT OF ADDITIONAL MATERIAL COVERED					
Modification	Description	Additional LOs	Small (1-3 LOs)	Medium (4-6 LOs)	Large (7+ LOs)
1	Introduce the concept of energy conservation and transfer for a Trebuchet, Introduce the related mathematical equation: m(weight)*g*∆h(weight) – m(ball)*g*∆h(ball) = ½ *m(ball)*V^2 (velocity of the weight and arm is ignored, in this case, energy is transferred from the gravitational potential of the weight to the gravitational potential and velocity of the ball and the overall mechanical energy is conserved through this process).	10			x
2	Use this equation to do the prediction (eg. Derive the expression for V in terms of other variables which gives a reverse relationship between V and m(ball) which means the heavier the marble, the shorter the throw)	9			x
3	Let several students give a presentation about the result and findings.	1	x		
4	Allow students to choose materials and build their own catapults and trebuchets using pictures and diagrams as a guide	3	x		

Appendix T: Matrices of Learning Outcomes Covered by Modified Sessions

	AQA Level 1						
	U2LO1	U2LO2	U3LO1	U5LO1	U5LO2	U5LO3	U7LO1
How Strong is your Material?				O	O	O	M
Plastic Fantastic?			M	O	O	O	
Modern Materials				O	O	O	O
Sports Science				O	O	O	O
Catapults and Trebuchets	M	O				M	

	AQA Level 2									
	U1LO4	U2LO1	U3LO1	U3LO2	U4LO1	U4LO2	U4LO3	U8LO1	U8LO2	U8LO3
How Strong is your Material?		M			M	O	M	M	M	
Plastic Fantastic?			M	M		O				
Modern Materials	O									M
Sports Science					O	O				
Catapults and Trebuchets					O	M				

	AQA Level 3													
	U3LO1	U3LO2	U3LO3	U7LO1	U7LO2	U7LO3	U8LO1	U8LO2	U8LO3	U8LO5	U9LO1	U9LO2	U9LO3	U9LO4	U9LO5
How Strong is your Material?	M	O	O	M			O	O	O			M			O
Plastic Fantastic?	O	O	O				M		M	M	M		M	M	M
Modern Materials	O	O	O	O	M										
Sports Science		M		O		O	M		M		M		M		
Catapults and Trebuchets							M				M	O	M		

	EDEXCEL Level 1						
	U1LO2	U2LO2	U2LO3	U5LO1	U5LO2	U5LO3	U7LO1
How Strong is your Material?				O	O	O	M
Plastic Fantastic?		M		O	M	O	M
Modern Materials					O		
Sports Science	M			O	O	O	
Catapults and Trebuchets	M		O				

	EDEXCEL Level 2								
	U1LO 3	U2LO 4	U3LO 1	U3LO 2	U4LO 1	U4LO 3	U7LO 1	U8LO 3	U8LO 4
How Strong is your Material?				O	M	M		M	
Plastic Fantastic?			M	M		O			
Modern Materials							O	M	O
Sports Science		O				O			
Catapults and Trebuchets	O					O			

	EDEXCEL Level 3									
	U3LO1	U3LO2	U3LO4	U7LO2	U7LO4	U8LO1	U9LO1	U9LO2	U9LO4	U9LO5
How Strong is your Material?	M	M	O			O				
Plastic Fantastic?	M	O	O							O
Modern Materials		O		M						
Sports Science	O				O	M	M	M	M	
Catapults and Trebuchets						M	M	M		

	OCR Level 1					
	F542LO1	F542LO3	F545LO1	F545LO2	F545LO3	F547LO1
How Strong is your Material?	M		O		M	M
Plastic Fantastic?			O	M	M	
Modern Materials			O		O	O
Sports Science		M	O		O	
Catapults and Trebuchets		O				

	OCR Level 2								
	F549LO3	F549LO4	F549LO5	F550LO1	F550LO3	F551LO1	F551LO2	F555LO3	F555LO4
How Strong is your Material?			M	O	O	M			
Plastic Fantastic?				M					
Modern Materials				O				M	O
Sports Science	O	M							
Catapults and Trebuchets							O		

	OCR Level 3													
	F558LO1	F558LO2	F558LO5	F558LO6	F561LO2	F562LO1	F563LO1	F564LO1	F564LO3	F564LO4	F564LO5	F564LO10	F564LO15	F564LO17	F564LO19
How Strong is your Material?	M	O	M	M			O							O	
Plastic Fantastic?	M	O	M								O			O	O
Modern Materials	M	O		O		M									
Sports Science	M	O			O		M	O		M			M	O	
Catapults and Trebuchets							M	O	M	M		O			

Appendix U: New Session Topics Proposed for the Royal Armouries

Armour Design Challenge

Session topics & activities:

a. Present the big picture of the design challenge of armour: how to protect yourself against weapons at the time with materials available.
b. Give a presentation about how ancient people solved this problem with materials and tools available at that time with power point slides and real objects. Present key features of the armours (e.g. Hammer plated alloy steel, rivet joints between pieces, extruded shape of chest plate, helmet features) and why it is built that way, and their pros and cons (e.g. Weight issue, ventilation issue, vision issue, mobility issue) from an engineering perspective. The existing object handling session can be incorporated into this part.
c. Eggstreme sport: could provide more building materials, such as plastic straws and wood sticks, to encourage novel design ideas.

Note:

The emphasis of this session is engineering design which is an important part in the Engineering diploma. The session starts with presenting the design challenge to make students think of the problem first before presenting them with the solutions people got back in time in forms of different types of amours.

This session is helpful for students to understand the engineering aspect of the amours so when students get into the Royal Armouries museum, they can see the engineering aspect of the historical amours in display.

Appendix V: New Session Topics Proposed for HMS *Belfast*

Ship Engine

Session topics & activities:

a. Presentation about the evolution of ship engine: from paddle wheel to turbine propulsion, from steam engine to internal combustion engine to nuclear engine.
b. Present in detail about the engine system HMS Belfast used. Talk about how this engine works, some of its key features (e.g. max power, fuel consumption, single stage gear reduction, steam turbine, high pressure turbine and low pressure turbine setup to increase efficiency), control system and how this huge engine is manufactured.
c. Hands on activity can be object handling of engine models, replica gears and steam turbine blades.

Note:

Engine is a great example of mechanical engineering. The impressive size, power and the complexity of the steam turbine engine installed on HMS Belfast should generate a great interest to students, especially those enrolled in the engineering diploma.

This session could have quite a few potential links to the curriculum of the engineering diploma on the aspect of engineering design, manufacturing and control engineering.

Ship Building

Session topics & activities:

a. Presentation about the principles involved in ship design, such as a low centre of gravity, good hydrodynamics, and efficient use of space.
b. Talk in detail about the design and building process of HMS Belfast. Present key features of the ship such as having 2 engines and 4 boilers in separate cavities to ensure the normal function of ship under attack.
c. Present the process of the design and building of HMS Belfast with historical pictures and movie clips from an engineering perspective.
d. Hands on activities similar to the "Launch! Ship building through the ages" exhibits.

(Picture shows the internal structure of HMS *Belfast,* photo courtesy of Bohua Wang)

Note:

As an important part of marine engineering, ship building involves many aspects of engineering including engineering design, manufacturing, materials and ergonomics.

A lot of session materials can be transferred from the current hands on exhibition in HMS Belfast "Launch! Ship building through the ages".

Appendix W: New Session Topics Proposed for the Joint Programme

Mechanical Joining Methods

Background on mechanical joint:

- Introduce the purpose of mechanical joints and concepts involved: degree of freedom, shear strength, tensile strength, and modes of failure.
- Discuss different types of mechanical joints: rigid joint; pin join; ball joint and sliding joints, etc.
- Comparison between these joint types regarding their strength, limitations and typical applications.

Examples of joining methods

Belfast:

- Welding for making the rigid ship body, pin joint for turret base, sliding joint for turret barrel.

Tower Bridge:

- Rivets joining multiple layers of steel plates; Pin joint connecting suspension bar to bridge body

The Royal Armouries:

- Armour plates were connected with push-in rivets and pin joints.

Related hands on activities

- Test the shear strength of pin joint using tensile strength machine
- Armour building activity using push in pins

Arms and Armours

Background information about the evolution of arms and armours

- Weapons: Initially using natural materials such as sharp stones and wood sticks, then move to metal, followed by the invention of gun powder and explosives

- Armours: Initially using natural materials such as leather, wood and stone plates, then move to metal and fabrics, modern armours using plastics, fiberglass and new materials.

Examples of weapon

- Belfast: guns, turrets, torpedoes. (picture shows turrets on HMS *Belfast*)

- The Royal Armouries: guns, swords, bow and arrow, trebuchet, catapult, ballista, etc.

Examples of armour

- Belfast: the plating of the ship; the layout of the engine rooms, to defend against underwater attacks, allowing them to run after one or more are hit.
- The Royal Armouries: chain mail; metal plate based armour.
- The Tower of London: walls and moat designed for defense against attack.

Related hands on activities

- Catapults and Trebuchets (Current Session)

Corrosion Resistance

Background information on the topic

- Different types of corrosion (physical, chemical, Biological)
- Methods of preventing it (protective paint, corrosion resistant material, surface treatment, drainage, etc.)

Examples of protection from corrosion

The Royal Armouries:

- Armours were built by rust resistant alloys.
- Cleaning processes used in museum to preserve the armours.
- Prevent the collection of sweat inside the armour by wearing cotton garments underneath.
- Drainage of the moat for the Tower of London.

HMS Belfast:

- Copper-based paint to prevent algae, barnacles and other sea creatures from growing on the ship hull.
- Cathodic Protection: weld a sacrificing zinc block on the ship hull
- Water drainage system to keep the ship dry.

Related hands on activities

- Doing tensile strength testing for two pieces of the same material in which one is rusted and the other is not to explore the effect of corrosion.
- Guns from the Sea (Current session)

Ventilation

Background information on the topic

- Introduce the concept of heat transfer, such as 3 ways of heat transfer: conduction, convection, radiation.
- Compare different ventilation systems: Building, ships, armour and space suit.

Examples of ventilation systems:

The Royal Armouries:

- Not much ventilation, cause over heating issue which prevent the knight from wearing the armour for a long time. Helmet can be taken off when not in a battle.

HMS Belfast:

- Specialised ventilation system that has insulation to direct heat from engines and machines out of the ship and away from the living and working areas.
- Use turbine blower to cool down engine room.

Related hands on activities:

- Try on pieces of armour and monitor temperature inside over time
- Staying Cool (current session)

Material Progression

Background information on the topic

- Material Science is omnipresent in our everyday life. Human history is defined by the material we use: Stone Age, Bronze Age, etc. Give a general background of material progression.
- Present some interesting new materials (e.g. shear thickening fluid, smart metal, etc.)

Examples of materials used

The Royal Armouries:

- Leather, mail, plate armour
- Metal armour
- Polymer based armours (modern police riot shields, etc.)
- Future of armour (Kaynemail, etc.)

HMS Belfast:

- (See Launch exhibit on Belfast)
- Early ships were wood
- Metal ships could be larger, sturdier, resistant to fire, etc.
- Moving toward use of fiberglass, carbon fiber, etc.

Tower Bridge:

- Older bridges use steel plates riveted together and casted beams
- Modern suspension bridges use cables

Related hands on activities:

- How Strong is Your Material (Current session)
- Plastic – Fantastic? (Current session)
- Modern Materials (Current session)

Load Distribution

Background information on the topic

- Introduce the concepts involved in the design of structural piece (e.g. stress concentration, center of gravity, effects of external forces)

Examples of mechanics

The Royal Armouries:

- Front extrusion of helmets, chest plates, etc. for redirection of weapons, thus minimize the damaging effect of external force.
- Curved surface to better distribute load across the armour piece and minimize deflection.

HMS Belfast:

- All windows and doors have rounded shape to prevent high stress concentration caused by the sharp corner.
- Low centre of gravity to stabilize the ship in the water.
- The bunks in the sick bay are designed to sway with the movement of the ship to keep a constant upright position.

Tower Bridge:

- Use pin joints to bear load of the bridge
- Use rigid and heavy structure to remain stable and balanced.
- Use counterweight on the movable gate to minimize the load on the motor.

Related hands on activities:

- How Strong is Your Material (Current session)
- Use Finite Element Analysis software (Solidworks COSMOS) to show students the stress distribution caused by external force.

Appendix X: Interview Protocol

Setting up Interviews

We obtained a listing of 61 schools offering the Engineering Diploma in the greater London area provided on the Department for Children, Schools, and Families website and cross referenced it with a book of secondary schools provided by our sponsor to find contact information for each school. We then called each school and asked to speak with the Headmaster about teachers involved with the Engineering Diploma. Spoke to either Headmaster or Headmaster's PA and got contact info for 15 teachers and other staff involved with the Engineering Diploma. Sent the following E-mail to these people and heard back from 3. Set up interviews with these three teachers.

E-mail to Contacts

Hello_____

We are a group from the Education Centre at the Royal Armouries in the Tower of London. We acquired your information from a listing of schools who are offering the Engineering Diploma. Currently, the Royal Armouries is working on developing a set of new educational sessions specifically for the Engineering Diploma. We would like to offer you and your school the opportunity to be involved in the creation of these programmes. Specifically we would like to meet with you to discuss ways in which you feel your programme could benefit from a Royal Armouries session, and in particular tailoring the programme to fit your needs.

If you are interested in speaking with our group to highlight some of the areas where you feel we could be of assistance please contact us by phone or e-mail. Alternatively if there is another person at your institution that you feel is better suited to receive this information please pass it along. Thank you for your time and assistance.

Sincerely,

The WPI Group at the Royal Armouries

Phone: 020 3166 6660 (when calling please ask to speak to the WPI group)

E-mail: towerd09@wpi.edu

Background Information

We are students from Worcester Polytechnic Institute in Worcester, Massachusetts, in the US, which is an engineering university. As a part of our degree requirements we complete a project called the Interactive Qualifying Project or IQP in which we take what we've learned about science, technology, and engineering and apply it to a real world problem or scenario. Many WPI students travel to project sites around the world for this project such as Namibia, Puerto Rico, Australia, and we are here in London. Our project is to work with the Royal Armouries

Education Centre to help them fit topics related to the new Engineering Diploma into their educational sessions. In order to do this we are looking to teachers, like you, to find out what would be most beneficial to the students and teachers involved. We are here for five more weeks and at the end of our time here we will be writing a final report with suggestions for the Royal Armouries.

Obtaining Consent for Recording

Beginning of interview (after background information):

> Would it be okay with you if we recorded this interview and use the information gathered in our formal report?

Once interview is completed:

> Thank you for your time, as noted earlier, some of the information that you have provided may be useful in our final report. A final copy will be made available if you so request. Do you have any questions for us? Thank you again.