Teaching Resources for the London Transport Museum

An Interactive Qualifying Project Report
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Report Submitted to:

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Abstract

To address the United Kingdom’s shortage of engineers, we developed the Full Speed Ahead Program and revised the Inspire Engineering Mentoring Program for the London Transport Museum; the former is a curriculum composed of ten modular lessons and teaches year 10 and 11 students about engineering in an interactive, hands-on environment while the latter focuses on engineering education and professional development for year 12 students. Both programs encourage students to pursue science and engineering by exploring these fields.

Acknowledgements

We recognize this project would not have been completed without the invaluable support of numerous individuals. We are greatly indebted to our advisors, Professors Constance Clark and Corey Dehner, whose professional guidance and tireless input were crucial to the success of our endeavor. Similarly, our sponsor at the London Transport Museum, David Houston, deserves nothing short of our deepest gratitude for his patience, expertise, and commitment to educational outreach programs.

Of course, there are several other individuals from many organizations who contributed to this endeavor; we recognize that without the help of these people, listed below in alphabetical order, the development of the Full Speed Ahead Program and revision of the Inspire Engineering Mentorship Program would not have been possible. We extend our thanks to all those involved with our project.

The London Transport Museum

- Rachel Craddock, Young People's Officer
- Gloria Gaspard, Young People's Skills Programme Coordinator
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- Tim Shields, Curator
- Maria Peters, Training and Creative Consultant

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- Mike Floate, Engineering Teacher
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- Those students who participated in a focus group regarding the Inspire Engineering Mentorship Program

- Those students who participated in a pilot of the Full Speed Ahead Program

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- James Dawson, Engineering Ambassador

- Rachel Jackson, Engineering Ambassador

- James Lloyd, Resource Manager

- Eric Wright, Engineering Ambassador

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Miscellaneous

- Martin Webber, Oxford Cambridge and Royal Society of the Arts STEM Sector Specialist

Executive Summary

Background

Interest in engineering among United Kingdom students is dwindling despite generous salaries and a respectable professional image. As of 2013, the number of students entering the United Kingdom's (UK) science, technology, engineering, and mathematics (STEM) industries will not fill the void created by the number of employees retiring from these fields and the new job openings in the expanding economy (STEMNET, n.d.).

Engineering UK, a non-profit organization which partners with engineering firms to demystify engineering in the public eye, claimed failure to meet the demand for engineers will result in the "damage of individual prosperity for employees" and could threaten the "economic sustainability of engineering employers" (Engineering UK, 2015, pg. 2 and pg. 1). In order to avoid potential economic problems, Transport for London (TfL) has partnered with several museums and technical secondary schools to reignite interest in engineering amongst the country's youth.

As part of this initiative, the London Transport Museum (LTM) sought assistance from the Worcester Polytechnic Institute's London Project Center to develop a program for students, ages 14 to 16 that expands upon the success of the Inspire Engineering Mentoring Program (IEMP). The IEMP is an engineering mentorship program for year 12 students (ages 16 and 17) focused on illuminating engineering careers and professionally developing participating students. Consequently, the goal of our project was to contribute to these efforts by developing a multi-disciplined, engineering-centric, project-based curriculum culminating in a tour of the LTM to inspire year 10 and 11 (age 14 to 16) students to pursue engineering. We also endeavored to streamline and improve the IEMP's materials based on stakeholders, mentors, and mentees' feedback who participated in its pilot.

Methodology

To achieve both goals, we created and completed a list of objectives for the development of the Full Speed Ahead Program (FSAP) and the revision of the IEMP. First, we defined the FSAP's learning outcomes and ensured the program matched the General Certificate of Secondary Education's (GCSE) standards. After a prototype of the FSAP was reviewed by our sponsor and educational experts, we piloted select activities of it with Royal Greenwich University Technical College (Greenwich UTC) students. We took note of the students' behavior, level of engagement and comprehension and made revisions based on the participating students' feedback.

Simultaneously, in order to enhance the IEMP; we collected data from various engineering, educational, and business professionals as well as the program's mentors and mentees. In addition, we reviewed and incorporated support for the Business Technology Education Council (BTEC) curriculum and added more activities, such as a session exploring personal statements for university applications, to help mentors relate to students and tailor the program to their mentees. Upon the completion of the FSAP and IEMP's materials, we presented the deliverables to our sponsor in the form of handbooks and a presentation.

Deliverables

We developed two programs: the brand new FSAP and the revised IEMP. Table i summarizes and compares the format of each activity. The key strength of both programs is their flexibility, or ability to quickly be restructured to match the needs of the students.

	FSAP	IEMP
Goal	To inspire students to pursue careers in STEM fields.	To promote the professional and personal development of students, especially in regard to STEM careers.
Number of Sessions	10 optional sessions (One to four hours per session)	A selection of 10 sessions (One hour per monthly session)
Deliverables	• Teacher Packet which includes Student Packet worksheets and a list of relevant LTM handling objects • Resources Packet which includes additional information for sessions	Mentor Handbook which includes student worksheets for each session
Learning Outcomes	1. To inspire students to pursue a career in engineering 2. To enable students to see the breadth and depth of engineering as a field 3. To guide students to see the benefits of 'soft skills' in engineering careers 4. To empower students to have the confidence in their ability to pursue careers in engineering.	1. To support students' growth personally and professionally 2. To develop the students' understanding of engineering
Target Audience	Key Stage 4 Year 10 and 11 GCSE students	Key Stage 5 Year 12 GCSE and BTEC students
Structure	Students complete each activity as a mock engineering firm, promoting teamwork. Upon completion of the curriculum teams will have made a full rail line with a company logo, train, track, tunnel, bridge, station, and mathematical analyses. The program concludes with a trip to the LTM (Session 10).	Students are sorted into groups of six with two junior mentors. The junior mentor is supported by a senior mentor who can provide engineering and teaching advice. To see the structure pictorially, view Figure 6.
Session Structure	Does vary, but generally: • Introduction • Research Phase • Design Phase • Build Phase • Recap/Discussion Phase	Varying
Types of Activities	• Hands-on activities • Written reports • Mathematical analyses • Presentation	• Hands-on activities • Professional writing (CV and personal statements) • Discussions about definition of engineering • Mock interview • Tutoring
Engineering	One optional visit	Every session

Ambassador Involvement		

Table i: A summary of the FSAP and IEMP

Findings

Based on our background research, interviews, and pilot of the program, we uncovered the FSAP findings. Our most important findings include: (1) the development of the learning outcomes; (2) the merits of a flexible curriculum, and (3) the effectiveness of diagrams in conveying concepts.

Full Speed Ahead Program

The first finding was the FSAP's learning outcomes, which we developed through extensive interviews with our sponsor and educational professionals; the learning outcomes are listed in Table i. These learning outcomes clearly outline the messages students should receive from participating in the program. All of the learning outcomes revolve around the notion, that engineering is an interesting and attainable goal.

Next, we discovered a flexible, modular program works best with a variety of schools, ranging from state schools to university technical colleges. A modular program is comprised of many sessions connecting to an overarching theme allowing teachers to run only the most relevant sections. Similarly, a flexible program can cater to all levels of student ability. For example, the Teacher Handbook now includes an "Above and Beyond" section to challenge excelling students.

The FSAP's final major finding demonstrated diagrams are far superior at conveying concepts than text. We realized this through the pilot at Greenwich UTC where students ignored large blocks of text in the Resource Handbook. This finding helped us revise the FSAP further as we removed as many long blocks of text as possible, even if it simply meant breaking lengthy essays into separate paragraphs.

Inspire Engineering Mentoring Program

Through an analysis of the existing IEMP curriculum and feedback from the program's coordinator, mentors, and students, we discovered the IEMP findings. In short, we found the program was too structured and did not allow mentors to adjust sessions to suit their mentees. Similarly, we found the length of the Student Handbook deterred students from utilizing it and meetings with larger student groups aided mentee engagement. Furthermore, students better engage with young engineers because these new professionals could relate to the mentees.

Recommendations

Our work not only yielded tremendous insights but also suggested additional areas for further program development. To begin, the FSAP must be run in full by teachers in a real classroom environment; only its direct application by education professionals can identify and resolve its flaws. Of course, to ensure the program runs smoothly we recommend the LTM hosts an orientation for participating teachers. Furthermore, we suggest accrediting the program as a GCSE through the Oxford Cambridge and Royal Society of the Arts (OCR) so as to bolster its legitimacy and encourage its use. Finally, the LTM should develop interactive, online resources for the FSAP to help engage students during each sessions' Research Phase. However, even as we outline possible areas for improvement, we are satisfied with the thoroughness and capabilities of both the current FSAP and IEMP and are confident that each can be successfully implemented.

Conclusion

We believe this project can inspire students to pursue engineering education and perhaps a career in engineering. A career in STEM is mutually beneficial; it can empower a person and affect millions more. This project will in some small way alleviate the challenges facing STEM education in the UK.

Authorship

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Executive Summary	All	All
Chapter 1: Introduction	Casey Broslawski	Casey Broslawski
Chapter 2: Background	All	Lauren Baker
Chapter 3: Methodology	All	Cameron Crook and Shannon Healey
Chapter 4: Findings	All	Shannon Healey and Casey Broslawski
Chapter 5: Deliverables	Lauren Baker	Shannon Healey
Chapter 6: Recommendations	Cameron Crook	Cameron Crook
Chapter 7: Conclusion	Casey Broslawski	Lauren Baker

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Table of Acronyms

Acronym	Full Title
BIS	Department for Business, Innovation, and Skills
BTEC	Business and Technology Education Council
CBI	Confederation of British Industry
CEBR	Center for Economic and Business Research
CISI	Chartered Institute for Science and Investment
DfT	Department for Transport
EC	European Commission
EU	European Union
FSAP	Full Speed Ahead Program
GCE A-Level	General Certificate of Education Advanced Level
GCSE	General Certificate of Secondary Education
GDP	Gross Domestic Product
GLA	Greater London Authority
Greenwich UTC	Royal Greenwich University Technical College
IEMP	Inspire Engineering Mentoring Program
IRB	Institutional Review Board
LTM	London Transport Museum
NAF	National Academy Foundation
OCR	Oxford, Cambridge, and Royal Society of the Arts
PAS Survey	Public Attitudes to Science Survey
PDF	Portable Document Format
PISEC	Philadelphia/Camden Informal Science Education Collaborative
RAAE	Royal Academy of Engineering
RRI	Responsible Research Innovation
UK	United Kingdom
STEM	Science, Technology, Engineering, and Mathematics
STEMNET	Science, Technology, Engineering, and Mathematics Network
TED	Technology Entertainment and Design
TfL	Transport for London
URL	Uniform Resource Locator
YPSP	Young People's Skills Program
WPI	Worcester Polytechnic Institute

Chapter 1: Introduction

The United Kingdom (UK) has a long history of scientific and technological achievements. From Isaac Newton's work in mathematics to the start of the industrial revolution to the recent announcement of plans to create the world's first tidal power plant (Harriban, 2015), British researchers and engineers have consistently produced quality, impactful innovations. While the UK only constitutes one percent of the world's population, it produces 10% of the world's scientific research (National STEM Centre, n. d.). Unfortunately, the UK's research efforts are threatened by a waning supply of new engineering professionals.

Interest in engineering among students is dwindling despite generous salaries and a respectable professional image. According to the 2014 Public Attitudes to Science (PAS) Survey, 88% of 1,379 adults believed engineers contribute to general welfare in a positive way, but only 23% of 508 students reported an interest in engineering (Charter Institute for Securities and Investments, 2014). The same PAS Survey also showed 31% of adults believed they were not clever enough to understand engineering (2014).

The adverse effects of this reality are beginning to take their toll on the nation's economic growth. The digital technology industry represents 27.1% of the UK's Gross Domestic Product (GDP) equating to a value of 329.17 billion pounds; it is anticipated to grow to 439.35 billion pounds by 2022 (Center for Economics and Business Research, 2015). To fuel this growth, companies in the UK must hire 182,000 engineers each year for the next seven years or lose 27 billion pounds in growth annually. Clearly the deficit of engineering talent will affect the entire United Kingdom far into the future.

Fortunately, several organizations are taking steps to incite a passion for science, technology, education, and mathematics (STEM) fields in young students. A proud member of these ardent advocates is the London Transport Museum (LTM). Home to 450,000 artifacts documenting 200 years of London's transportation history, the LTM is brimming with examples of engineering at its finest, which makes it the perfect place to correct misconceptions about the field (LTM, 2015). Capitalizing on this position, the LTM has paired with Transport for London (TfL) and Royal Greenwich University Technical College (Greenwich UTC). The former is responsible for safely ferrying millions of Londoners to their destinations every day and thus has a great pool of talented engineers, while the latter has direct contact with technically apt students.

Upon realizing the complementary nature of the LTM's resources, the expertise of TfL's engineers, and the passion of Greenwich UTC's students, the three have collaborated on such education initiatives as the Inspire Engineering Mentoring Program (IEMP). This joint effort provides mentorship, counseling, and career advice to year 12 (age 16 to 17) students. Due to the success of the year 12 program, the LTM, TfL and Greenwich UTC IEMP supervisors requested a similar program be developed for year 10 and 11 students (ages 14 to 16).

We endeavored to satisfy this request by applying the lessons learned from the largely successful Inspire Engineering program to a younger group of students. The goal of our project was to design an educational program highlighting engineering examples and applications so year 10 and 11 students may consider engineering as a potential field in the future. We were responsible for creating a curriculum drawing on the strengths of the LTM, TfL, and Greenwich UTC and impressing upon these pupils the interesting and dynamic challenges faced by London's transportation engineers. We hope that by participating in this curriculum, students learn what engineers contribute to society and understand their own potential to join this field. In order to develop an interactive curriculum to engage younger audiences, we examined the standards of engineering in the General Certificate of Secondary Education (GCSE) and

Business and Technology Education Council (BTEC) for year 10 and 11 students. Through analysis of these two curriculums, we linked classroom concepts to practical applications that will excite students to further their education in the STEM subjects.

Furthermore, we reviewed the IEMP's curriculum and made improvements based on stakeholder, mentor, and mentee feedback; here, our goal was to analyze and implement these suggestions to increase the effectiveness of the program. Though we added some additional material to the deliverables, we streamlined the curriculum and made meetings and instruction more open-ended and adaptable.

Included in this report is a full write-up of the steps we took to reach the aforementioned goals. In Chapter 2, the background chapter, we provide context for our work, exploring the current state of engineering, the psychology of education, and educational systems and requirements in the UK. In Chapter 3, the methodology chapter, we explain the sequence of objectives outlining the development of the curriculum and the revision of the IEMP materials. In the findings section, we discuss the construction of the curriculum based on our synthesized data. We provide a description of the resulting programs in Chapter 5. The report concludes with recommendations for further research, along with a summary of our project and its implications. The next great British engineer is out there, learning their times tables and the scientific method; initiatives such as ours will ensure a continued interest in engineering and technology among London's youth.

Chapter 2: Background

As of 2013, the number of students entering the United Kingdom's (UK's) science, technology, engineering, and mathematics (STEM) industries will not fill the void created by the number of employees retiring from these fields and new job openings in the expanding economy (STEMNET, n.d.). Engineering UK, a non-profit organization which partners with engineering firms to demystify engineering in the public eye, claimed failure to meet the demand for engineers will result in the "damage of individual prosperity for employees" and could threaten the "economic sustainability of engineering employers" (Engineering UK, 2015, pg. 2 and pg. 1). In order to avoid potential economic problems, the government has partnered with several museums and technical secondary schools to reignite interest in engineering amongst the country's youth.

In this chapter, we explore the complex issue of waning interest in STEM by discussing the current state of engineering in the UK, the nation's educational system, effective teaching methods, and the progress our sponsor, the London Transport Museum (LTM), and its partners, Transport for London (TfL), and Royal Greenwich University Technical College (UTC), have made in generating an interest in STEM fields in the UK.

2.1: Exploring the United Kingdom's Need for Engineers

The UK is a dynamic contributor to the world's technological advancements, leading such projects as the most recent attempt to break the land speed record (Bloodhound Supersonic Car (SSC), n.d). In this section we explore the engineering field, explaining what engineering is, how it is perceived by the general public, and other current initiatives involving engineers.

Engineers use man's knowledge of the world to improve the human condition. Jim Lucas of *Live Science,* one of the world's dominant websites for science-related news (Purch, 2014), describes this field as “the application of science and math to solve problems...it is engineers who are instrumental in making [scientific] innovations available to the world” (2015). In this way, engineering is the ultimate human endeavor.

The aspect of engineering most relevant to our sponsor the LTM is transportation engineering, a subset of civil engineering (Science Buddies, 2015). Detailed descriptions of our sponsor and their affiliates are included in Appendix B. Science Buddies, a non-profit website specializing in science education, explained “The goal of the transportation engineer is to move people and goods safely and efficiently” (2015). Transportation engineers consider scientific ideas and available resources to create and maintain infrastructure like airports, railways, and bus networks (Id). As London’s population grows, more demand will be placed on the city’s public transportation system, emphasizing the role of transport engineers. Population data taken from *The Economist,* a London-based newspaper, highlights this trend; the values are represented graphically in Figure 1.

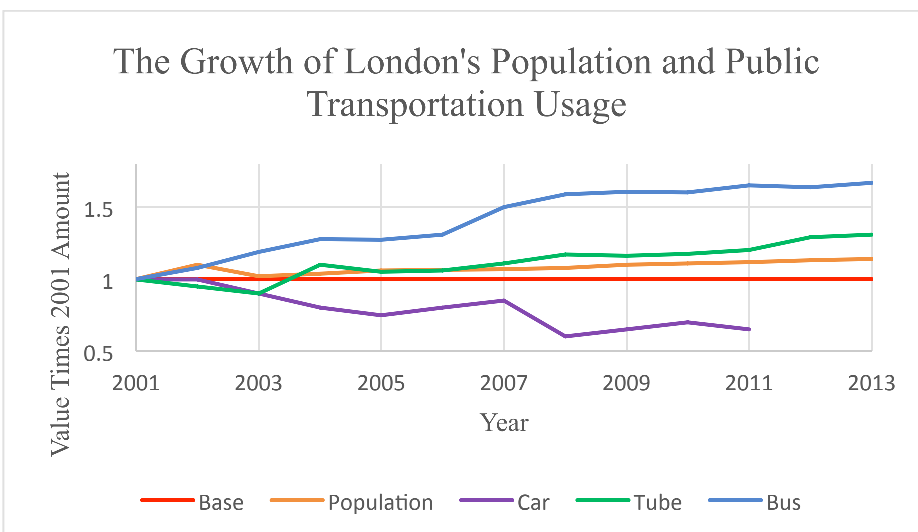

Figure 1: The scope of public transportation. Note: Data collection ceases at June, 2013.

Note the article cites TfL and the Greater London Authority (GLA), the city’s governing body (GLA, n.d.). Figure 1 clearly indicates as time progresses less and less people are traveling by car in London, rapidly increasing the number of people using public transportation services (The Economist, 2013). Therefore, many more transportation engineers are required to satisfy the rising demand for mass transport. While transportation engineers tend to work behind the scenes, their efforts are critical to maintaining and furthering the infrastructure of the UK.

2.1.1: Engineering in the UK

In spite of the variety and importance of an engineer's work, the profession is in decline in the UK. Matthew Harrison, the Director of Education for the UK's lead engineering professional body, the Royal Academy of Engineering (RAE), wrote in the report Jobs and Growth, "There is good econometric evidence the demand for graduate engineers exceeds supply and the demand is pervasive across all sectors of the economy" (2012, pg. 3). He asserted that the UK must produce a minimum of 100,000 STEM professionals to prevent inhibitions to economic growth (Id). Unfortunately, the 90,000 STEM graduates leaving British universities annually are far from fulfilling this requirement because as many as 26% of them do not ultimately work in STEM fields (Id). Harrison calculated that to truly close the talent deficit, 50% more STEM graduates must be produced every year (Id).

Presently, the UK is far from meeting the industry's demand for talent, because, in spite of a modest rise in applications to British universities' engineering departments discussed in another report published by the RAE, Skills for the Nation, the acceptance rate for these applicants has stagnated at about 5% (RAE, 2013). This suggests that while there is still some interest among students to become engineers, universities are not ready to handle these extra attendants, let alone the amount necessary to fill the quota described by Harrison.

Furthermore, Professor of Chemical Engineering John Perkins, in his Review of Engineering Skills for the UK's Department of Business, Innovation, and Skills (BIS), has reported as many as 32% of the pupils in STEM departments at universities in the UK are international students (Perkins, 2013). This practice is untenable because many of these students are not granted the necessary immigration status to practice their trade within the UK after graduation (Id). This means the UK is denying work to fully certified STEM graduates at a time when their skills are in short supply.

The cause of the UK's deficit of engineers is both multi-faceted and complex. The aforementioned reports show that the nation's universities do not have the capacity to train enough engineers to meet the industry's demand (RAE, 2013), while many of the STEM graduates they do produce are unable to stay in the country due to their immigration status (Perkins, 2013). A solution to the UK's STEM crisis will require work in the nation's higher education and immigration systems. The fact remains, however, there are far too few applicants to STEM university programs to fill the talent gap Harrison outlines (2012).

2.1.2: Public Views of Engineering

In order to understand why STEM in the UK is suffering from a lack of interest amongst the nation's youth, we must explore public perception of engineering. Two studies which provide information about this matter are the Public Attitudes to Science (PAS) Survey 2014 and Eurobarometer 401, "The Responsible Research and Innovation (RRI), Science and Technology." Sarah Castell, Anne Charlton, and Michael Clemence of the market research firm Ispos Mori headed the former study commissioned by the UK's Department of Business, Innovation and Skills (BIS), the government body responsible for promoting and monitoring the UK's economic growth (Ispos MORI, 2015; GOV.UK, 2015). The European Commission (EC), the executive body of the European Union (EU), commissioned Eurobarometer 401 (EC, 2015);

note that this study included the UK in its survey, along with all other member states of the EU (EC[1], 2013).

These reports show most of the UK's public have relatively high faith in engineers, with 88% of 1,379 people surveyed in the UK saying engineers have a positive impact on society (Castell, Charlton, & Clemence, 2014), well above the 77% of 27, 563 Europeans with the same opinion (EC[1], 2013). Furthermore, the PAS survey has shown that the percentage of people who feel it is important to learn about the role science plays in their lives has risen from 57% of over 1,800 adults in 1988 to 72% of a similarly sized group in 2014; in fact, 84% of this group agree that "science is such a big part of our lives that we should all take an interest" (Castell, Charlton, & Clemence, 2014, pg. 3). Again, this is a much higher proportion than the 53% of the 27,563 Europeans who say they are interested in scientific and technological developments (EC[1], 2013). See Table 1 for a comparison between these two studies. Clearly the people of the UK value the work being done by STEM professionals, especially in comparison to the rest of the EU.

Comparison Between Eurobarometer 401 and PAS Survey			
Study:	Eurobarometer 401	PAS Survey (Two rounds of Data Collection)	
Year:	2013	1988	2014
Participants:	27,563	1,800+	1,379
Do engineers have a positive impact on society?	77% say 'Yes'	No data	88% say 'Yes'
Do you take an interest in scientific developments?	53% say 'Yes'	57% say 'Yes'	84% say 'Yes'

Table 1: A summary of Eurobarometer 401 (EC[1], 2013) and the PAS Survey (Castell, Charlton, and Clemence, 2014).

Why, then, is there a growing shortage of engineering talent in the UK? The PAS Survey included a section on 16 to 24 year olds, the demographic who will soon enter universities and the workforce. Unfortunately, survey results show, in spite of the trends discussed above, people in this age group are both uninspired and unaware of the importance of STEM work. Only 52% of 510 youths felt well informed about scientific research and developments, while 59% of 315 felt engineering was uninteresting (Castell, Charlton, & Clemence, 2014). Furthermore, 18% of the same group of 315 did not think they were smart enough to understand engineering (Id). In regards to their educational experience, of 510 youths surveyed, only about half felt their science education has been useful in everyday life, while about one in four felt their experience in school made science unappealing (Id). These statistics from the PAS Survey are included in Table 2; note that the 315 people in "Booster survey" are included in the "Full group" of 510 participants.

Youth Views of Engineering	
Sub-Section of PAS Survey	
315 Participants (Booster survey)	510 Participants (Full group)
• 59% felt engineering is interesting • 18% felt they were not smart enough to understand engineering	· 52% felt well informed about scientific research and developments · 51% felt their science education has been useful in everyday life · 24% felt their experience in school made science unappealing

Table 2: An analysis of the responses from 16-24 year olds in the PAS Survey (Castell, Charlton, and Clemence, 2014)

The results shown in Table 2 suggest that young adults in the UK are not enthusiastic or aware of the importance of STEM work. Exacerbating this problem are findings highlighted in a 2014 report published by the Chartered Institute for Science and Investment (CISI), one of the UK's largest financial services firms. The goal of the survey was to quantify public attitudes towards various professions, and in the end it showed only 14% of 1,142 parents and 23% of 847 teachers surveyed truly understood what engineers do (CISI, 2014). Table 3 lists the statistics generated from this survey. Wellcome Trust, a charity dedicated to supporting talented researchers of all fields of study (Wellcome Trust, n.d.), published a report which weighs in on the effect of this lack of understanding, saying "The activities of adult friends of the family, teachers from primary school and friends from primary school (and their parents) are the main drivers for tweens to take up activities…" (Lloyd, Neilson, & King, 2012, pg. 30). If teachers and parents cannot provide a consistent explanation of an engineer's job, then young minds will be impeded from entering a STEM profession.

Educating Role Models	
CISI Data	Engineering UK Data
• 14% of 1,142 parents had a clear idea of what engineers do • 23% of 847 teachers had a clear idea of what engineers do	• 42% of 862 parents admitted their understanding of engineering increased. 68% reported being more likely to suggest their accompanying minor pursue a career in STEM • 43% of 83 teachers admitted their understanding of engineering increased. 70% reported being more likely to suggest their accompanying minor pursue a career in STEM

Table 3: Parents' and teachers' understanding of engineering (2014; 2015)

Fortunately, Engineering UK has shown that parents and teachers can be taught about STEM through educational outreach programs. After attending one of their sponsored engineering events aimed at exciting young people ages 11 to 14 about STEM, many of these role models reported not only gaining insight about what engineers do, but that they were also more likely to suggest a career in STEM to their accompanying minor (Engineering UK, 2015). The effects of attending a sponsored engineering event on parents and teachers are quantified in Table 3. Many UK residents are not familiar with the responsibilities of an engineer, which deters students from pursuing careers in STEM. However, there are ways to educate the public about these fields.

2.1.3: A Current Engineering Project in the UK

Because construction initiatives directly affect many people, they are excellent means to exemplify the work of engineers and its benefit to the public. Of all these projects, perhaps the largest and most relevant to London's transportation infrastructure is the Crossrail endeavor. Please note that the following information is summarized in Table 4.

Crossrail is the result of a joint effort between TfL and the UK Department for Transport (DfT). Crossrail is a significant upgrade of London's rail network; construction began in 2009.

Upon completion in 2018, 24 new trains will carry 72,000 passengers per hour along 100 kilometers of railway (Crossrail, 2015). Crossrail administrators expect 200 million people to take advantage of the system annually, which represents a 10% increase in London's rail capacity. Ten brand new stations will enable 1.5 million people to reach key economic sections of the city in 45 minutes or less (Id).

To help see the program to fruition, Crossrail has employed 10,000 people who, working across 40 construction sites, have, as of 2015, already reached such milestones as completing the digging of 90% of the 42 kilometers of new underground rail tunnels (Crossrail, 2015). Specifically, Crossrail employs STEM professionals for what it calls "major civil engineering works," which includes tunneling, city planning, and station design (Id). Crossrail recognizes and appreciates the work of its engineers and is acutely aware of the skills shortage facing the profession (Id). To help ensure STEM education continues to thrive in the UK, Crossrail has taken several steps to ensure talented professionals enter the workforce for generations. Four hundred apprentices are working on Crossrail, developing practical skills, including a knowledge of several aspects of technology and engineering. Also, through its Young Crossrail Program, 1,000 Crossrail ambassadors have spent a total of 100,000 hours teaching 10,000 students from ages 11 to 19 about STEM. The six partner schools involved in this program are all situated along Crossrail's planned route, making the material directly relevant to the students (Id).

<table>
<tr><th colspan="3">Crossrail Facts and Statistics</th></tr>
<tr><th>Upgrades</th><th>Employees</th><th>Young Crossrail Program</th></tr>
<tr><td>10 brand new stations
24 brand new trains
100 kilometers of track, including 42 kilometers of new underground rail tunnels
90% of tunneling completed as of 2015
10% increase in London’s rail capacity
200 million anticipated passengers, annually, at a rate of 72,000 passengers an hour
1.5 million additional people will live within 45 minutes of London’s key economic sectors upon the completion of the railway</td><td>10,000 full employees
400 apprentices
STEM professionals employed for “major civil engineering works.” This includes tunneling, city planning, and station design</td><td>Six partner schools, including Greenwich UTC. Each is located along Crossrail’s planned route.
Focuses on students ages 11 to 19
1,000 Crossrail ambassadors
10,000 students have been involved in the program
100,000 hours have been spent at partner schools by Crossrail ambassadors</td></tr>
</table>

Table 4: An overview of Crossrail (Crossrail, 2015)

The UK has a long history of engineering accomplishments, and while the industry is currently suffering from a lack of interest from young students, researchers and companies are creatively working to understand the cause of this problem and to educate and inspire the next generation of engineers.

2.2: Education

In 2013, the Right Honourable Nicky Morgan, Education Secretary of the UK, publicly recognized UK students graduating from the GCSE and A-levels were not sufficiently prepared for universities (2015). In response, the government passed recent reforms of these two standards (Morgan, 2015). In fact, the government has teamed up with various organizations to offer more resources to both students and teachers (Id). To explore these changes, we examine how people learn and the resources available to students and teachers in the following sections.

2.2.1: Psychology of Education

Martin Luther King Jr. once said, “The function of education is to teach one to think intensively and to think critically” (King, 1947). Education is more than a test score or a grade. The ultimate purpose of education is to help students retain information they may call upon in the future to make informed decisions which shape not only their lives but also the world around them. Though the human ability to learn and communicate knowledge is responsible for our thriving species, our learning characteristics vary between individuals and are far narrower than we know. In order to optimize the delivery of information educators must consider elements of human learning, such as *working memory*, the *theory of multiple intelligences*, and the merits of different teaching styles.

Working Memory: When individuals are asked to remember five random words and then perform a series of thought intensive tasks, such as multi-digit multiplication, their initial word retention on average drops to less than half (Doolittle, 2013). This exemplifies the shortcomings of working memory, the portion of our mental capacity devoted to absorption of new information. Typically new information such as a phone number, is stored in working memory where it will be forgotten in the next ten to twenty seconds if the individual does not immediately use it (Id).

Peter Doolittle, a professor of educational psychology at Virginia Polytechnic Institute and State University and Executive Director of the Center for Instructional Development and Educational Research, shared several strategies to improve retention during a Technology Entertainment and Design (TED) Talk in 2013. The first method involves the immediate use of the information in a mental process such as discussing the concept with another person or connecting it to previous knowledge. In addition, humans naturally seek patterns and meaning in the world, thus requiring us to structure and categorize information into separate mental compartments. This process allows us to reconcile new information against previous assumptions. In doing so, we greatly increase the retention rate of new material and assimilate it into our long term memory (Id).

Theory of Multiple Intelligences: Other theories examine different elements of learning. Howard Gardner, a developmental psychologist, proposed the theory of multiples intelligences (Gardner, 2008). His work postulates a person's unique profile is comprised of a number of different intelligences, including musical, bodily-kinesthetic, logical-mathematical, linguistic, spatial, interpersonal and intrapersonal varieties (Id). Despite the compartmentalization, exceptional intelligence in an individual is not isolated to one category and having an exceptional skill set often requires prowess in more than one area (Id). Given the variety of distributions possible across various intelligences the optimal learning methods for each person are different as well. Someone who possesses a significant spatial intelligence would likely benefit from hands-on activities and be more visually oriented, whereas a person with an exceptional linguistic intelligence would likely benefit from audible or text-based learning methods (Id).

Teaching Styles: Based on this view of intelligence, teachers may utilize two prominently known teaching styles, lectures and projects. By introducing students to new information and giving them an opportunity to apply said information, project-based learning holds significant advantages to lectures (Heinricher, 2013).

In a project-based environment students are able to exercise new knowledge immediately and are therefore more likely to retain the information. Furthermore, a project-based task would be more likely to employ multiple learning styles allowing students of different learning persuasions to benefit from the same material. This is a stark contrast to lectures where students are bombarded with information over an extended period of time with little possibility of discussion and application of topics (David, 2008).

The most effective programs involve cooperative learning methods and encourage student interaction according to the November 2009 "What Works in Teaching Maths? Report Summary" from the University of York (Slavin, 2009). Additionally, a study conducted by Jo Boaler, a Professor of Mathematics at Stanford, found that students of one secondary school in the UK using project-based learning methods significantly outperformed their counterparts at a control, lecture-centric school (David, 2008). For example, three times as many students in the project-based curriculum passed the national exam (Id).

2.2.2: Education Standards

The United Kingdom's public education system has flexible paths for different learners. All students begin their education with the National Curriculum. After completing this curriculum, students can make a decision between the traditional education system and an alternative education system (Engineering UK, 2015). If a student should wish to choose the traditional system, then they will take the General Certificate of Secondary Education (GCSE) from ages 14 to 16. Following this, students can choose whether or not they wish to add another degree onto their curriculum vitae by choosing to take A-Levels or the International Baccalaureate. Alternative educational systems that students may choose to take include the BTECs, traineeships, and apprenticeships (Id). Figure 2 provides a visual explanation of the progression of the UK curriculum discussed in this paper.

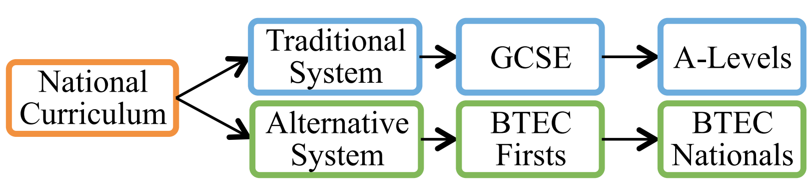

Figure 2: Progression of education systems in the UK

The National Curriculum in England: This curriculum, set by the Department for Education, provides students with the necessary foundational knowledge for them to move forward in their education. All schools must follow this education system. The curriculum is broken down into four key stages: key stage 1 (ages 5 to 7), key stage 2 (ages 7 to 11), key stage 3 (ages 11 to 14), and key stage 4 (ages 14 to 16). The program offers twelve subjects, including English, math, and science (Department for Education, 2014). The subjects studied in this curriculum give students enough background so that they are able to continue their education through advanced education systems. For further detail on which subjects are taught when in the math and science curriculums, please refer to Appendix A.

The General Certificate of Secondary Education: The GCSE is a qualification taken by students ages 14 to 16. It marks their graduation from Key Stage 4 of secondary education in England, Wales, and Northern Ireland (BBC, n.d.). The qualification offers students the chance to study various subjects, ranging from mathematics to foreign languages to science. As of February 23rd, 2015, the UK Department for Education passed a GCSE reform, applying only to England. This reform strives to make the curriculum "more challenging" to ensure that "pupils are better prepared for further academic or vocational studies" (Morgan, 2015).

The new curriculum will be designed for two years of study and all students will be required to take all necessary exams in May of the second year (GOV.UK, 2015). After studying this curriculum, students are encouraged to further pursue their studies with the General Certificate of Education Advanced Level (GCE A-Level). The A-Levels are beyond the scope of this report. To see the detailed breakdown of the new GCSE curriculum as well as further subjects offered in the GCE, please see Appendix A.

2.2.3: Alternative Education

The United Kingdom offers several additional teaching resources for its students to abet the standard curriculum, including the Business and Technology Education Council curriculum (BTEC), traineeships, and apprenticeships. Alternative education refers to vocational studies that are not solely exam-based. Note that for use in this report "alternative programs" is taken to mean any learning environment set up outside of a normal classroom setting, such as museum-based programs.

The Business and Technology Education Council Firsts (BTEC Firsts): The BTEC Firsts are a vocational qualification taught to students between the ages of 14 and 16. They are equivalent to the GCSEs. With this curriculum, students have the ability to build their own course load based on their interests. The subjects that are offered include but are not limited to: applied science, engineering, information technology, and vehicle technology. Should students wish to pursue their education with this curriculum, then they would study the BTEC Nationals (Pearson, n.d.). For a more detailed breakdown of the courses offered, see Appendix A.

Traineeships and Apprenticeships: These two programs often work in tandem, with a traineeship leading up to an apprenticeship. The former can last up to six months and provide a student with English and mathematics if needed and help them gain work experience (GOV.UK, 2015). Apprenticeships are a good path to qualification because they allow learners to apply theoretical knowledge to real life situations, learn how to effectively communicate, and gain work experience (Pearson, n.b.d.). This may be useful for learners better suited to application or project-based learning. There are four possible levels of apprenticeships: intermediate (level 2), advanced (level 3), and higher (level 4 and 5). BTEC offers a variety of engineering apprenticeships ranging from construction to ceramics manufacturing to rail engineering (Id).

Extra-curricular programs: Another method to introduce and support pupils' interest in STEM fields is through extra-curricular programs such as the LTM's Young People's Skills Program, Engineering UK's Tomorrow's Engineers, and the Science, Technology, Engineering, and Mathematics Network (STEMNET) (STEMNET, n.d.).

The first extra-curricular program is STEMNET. This organization works with schools and STEM employers to enable students to understand real world applications of STEM subjects as well as meet inspirational leaders in these fields (STEMNET, n.d.). STEMNET offers three programs to inspire students to pursue STEM fields in the future: STEM Ambassadors, STEM Clubs Programme, and Schools STEM Advisory Network. For further information on these programs, please see Appendix A (Id).

Tomorrow's Engineers is an extracurricular program dedicated to inspiring the next generation of engineers in the UK and is led by Engineering UK and the Royal Academy of Engineering. It utilizes hands-on activities, theatre shows, career resources, and other methods to communicate its mission to students (Tomorrow's Engineers, n.d.).

Another extra-curricular program is the London Transport Museum's Young People's Skills Program (YPSP). It is designed for students 16 and younger to generate interest in STEM fields and provides mentorship, counseling, and career advice to year 12 and 13 (ages 16 to 18) students. Sources for STEM education are becoming more readily available due to the efforts of several museums (D. Houston, personal communication, April 24, 2015).

2.2.4: Learning STEM in Museums

Students also learn about STEM in visits to museums. A successful interactive museum design is defined in the Philadelphia/Camden Informal Science Education Collaborative (PISEC). PISEC outlines seven characteristics that guide interactive exhibit development to increase family-based learning (Borun, 1998). To see the breakdown of these characteristics, consult Appendix C. In this section, we discuss a few principles in exhibit design that help predict whether an exhibit will engage visitors and help them retain information (Borun, 1998). We conclude this section by relating this concept to STEM education in classrooms.

Various exhibit setups: In recent years, exhibit design in museums has made a shift from static, wall-mounted displays to multi-sided, interactive exhibits, known as dynamic exhibits, which encourage discussion between visitors and lead to increased learning (USS Constitution Museum Team, n.d.). Note that while dynamic exhibits are generally regarded as more effective than their static counterparts, the high cost of an interactive design, the nature of the content being presented, and a display's need to engage large groups are all considerations in the exhibit design process (Museum Exhibit Design, 2015).

One case study completed by PISEC was a redesign of the *Caribbean Beach* (formerly *Barrier Beach*) exhibit, a diorama with organisms in a beach habitat accompanied by informational panels. The exhibit provided limited opportunities for families to develop a deeper understanding as it was mainly observational in nature. The development team created an activity kit for families to use in the exhibit, giving visitors the opportunity to interact with the exhibit through assembling puzzle pieces, printing images on a postcard placing animals in their correct habitats, and exploring a book depicting camouflage through semi-transparent pages. The changes yielded positive results, as "visitor conversations ranged from simple identification to discussions about camouflage and habitat," which was an improvement from the initial observations (Borun, 1998, pgs. 37-38). After receiving positive findings, the aquarium produced several copies of the kit, which became a regular offering at the exhibit.

Interactive exhibit design should be avoided if the engaging aspects of the display have the potential to confuse and distract visitors. Upon observing a new interactive exhibit at the Exploratorium, an “eye-opening, playful” science museum in San Francisco (Exploratorium, n.d), curators found it was too demanding to allow visitors to understand the concept it was trying to convey. This exhibit gave visitors the chance to find beating heart cells in a petri dish using a microscope. Initially, observers could move and focus the microscope to find such cells in the dish, but the pockets of cells were found to be too difficult to identify for the average visitor. This interactive exhibit led to negative outcomes (i.e., the visitor not finding beating heart cells), and it was therefore a drawback (Allen, n.d.). The museum eliminated the interactive display in this scenario, allowing only museum staff to control the microscope (Id). Interactive displays, when properly executed, will enhance visitor learning.

Active Learning: Eilean Hooper Greenhill, a professor of museum studies at the University of Leicester, defined three broad approaches to teaching: the symbolic mode, learning through reading text or through verbal forms of communication; the iconic mode, learning through pictures or watching a film or demonstration; and the enactive mode, learning through handling objects, or through participating in activities. Hooper asserted that museums rely too much on the symbolic mode, failing to create opportunities for iconic or enactive learning, which produces “an exhibition, or a presentation, with only one major communicative channel. This will inevitably restrict the range of audiences with which the exhibition will successfully communicate” (Hooper-Greenhill, 1994, pg. 146).

Active learning is not only utilized in museum exhibits, it is also an effective teaching method in STEM curriculum. Richard R. Hake, a Physics Professor at the University of Indiana Emeritus, analyzed standardized exam scores from 62 introductory physics courses and suggested that the use of interactive strategies "enhances problem-solving" abilities and "can increase mechanics-course effectiveness well beyond that obtained with traditional methods" (1998, pg. 64). Pre- and post-test results showed students in the interactive-engagement courses understood more concepts than the students learning through traditional methods (Hake, 1998).

2.3: Collaboration Between the LTM and their Affiliates

The London Transport Museum (LTM), Transport for London (TfL), and Royal Greenwich University Technical College (UTC) are working to further STEM education in the UK, oftentimes combining their individual expertise to produce comprehensive programs for students of all ages. As an authority on London's public transportation history (LTM, 2014), the LTM often collaborates with the organization responsible for running that infrastructure today, TfL (TfL, n.d.). In turn, engineers at TfL share their knowledge with students at Greenwich UTC through mentorship programs (Eatherden, 2015).

One such education effort is the Inspire Engineering Mentorship Program developed in May of 2014 by four WPI students, Matt Jackson, Sarah Quatieri, Thomas Kotselak, and Leah Pervere. The goal of the Inspire program is to give Greenwich UTC's year 12 students (ages 16 to 17) a "deeper understanding of engineering and development in both their personal and professional lives" (Jackson, Quatieri, Kotselak, & Pervere, 2014, pg. 6). Based on previous research as well as sponsor input, the WPI team decided to use TfL mentors to facilitate the program to ensure "students can gain insight into what the STEM fields truly are, as well as be encouraged to pursue careers in these fields" (Id, pg. 7). Pupils participating in the program are divided into groups of three based on their compatibility and assigned a mentor from TfL's Engineering Ambassadors to advise them at ten monthly meetings. The WPI team decided to use recent STEM graduates as mentors for the program because it was believed they could better relate to the young students and would have more time to spend with the aspiring engineers (Id). The team focused their program on three major themes: overview of engineering, professional development, and personal development (Id). The themes were divided over the ten meetings; a breakdown of the program can be found in Table 5.

Themes	Engineering Overview	Professional Development	Personal Development
Meetings	1 to 3	4 to 7	8 to 10
Example Topics	Different fields of engineering What engineers do on a day to day basis	How to interview How to write a résumé	Communication Problem Solving

Table 5: Breakdown of Mentoring Sessions (Jackson, Quatieri, Kotselak, & Pervere, 2014)

In an effort to further attract primary and secondary students to STEM fields, the LTM has reached out to the Worcester Polytechnic Institute's London Project Center to develop an inspirational STEM curriculum focused on London's interesting history of public transport, utilizing the resources of the LTM, TfL, and Greenwich UTC, and to review and improve the Inspire Mentorship program based on the impressions of the mentors; these are the goals of our project. A detailed description of our sponsor and their affiliates is included in Appendix B. In the next chapter we discuss our methodological approach to completing our project's goals.

Chapter 3: Methodology

Our sponsors are combating the United Kingdom's shortage of engineers by offering a wide variety of educational programs aimed at exciting young students about science, technology, education, and mathematics (STEM). The goal of our project was twofold: (1) to contribute to our sponsor's endeavors by developing an engineering-based curriculum to help inspire year 10 and 11 students (ages 14 to 16) to pursue STEM careers, and (2) to review and improve the Inspire Engineering Mentoring Program's (IEMP) materials. Both programs draw on the experience of Transport for London's (TfL) Engineering Ambassadors, the project-based curriculum of Royal Greenwich University Technical College (Greenwich UTC), and the vast store of information at the London Transport Museum (LTM). The Full Speed Ahead Program (FSAP), which addresses our first goal, uses a project-based STEM curriculum to highlight London's transportation infrastructure and culminates in a trip to the LTM. Our work on the IEMP involved collecting feedback from TfL mentors, reforming the program's leadership structure, providing additional resources to mentors, adding more hands-on activities to the curriculum, and streamlining the handbooks. Figure 3 provides a clear outline of the individual objectives we completed to meet the challenges facing STEM education and satisfy our project's goals.

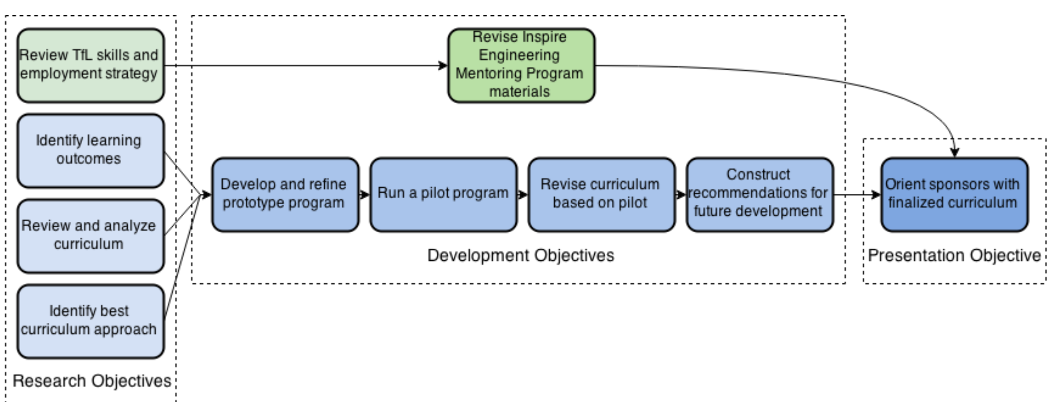

Figure 3: Methodology flow chart

Note how the individual objectives in Figure 3 can be grouped into three stages: a research phase, a development phase, and a presentation phase. Upon our arrival in London, we familiarized ourselves with our sponsor's and their partners' resources and identified the gaps in their current initiatives; the program we developed addresses these areas. We created the FSAP over several weeks to allow for input from our sponsor and an analysis of the collected data. After the completion of a partial pilot of the FSAP, we used our remaining time in London to finalize our project and submit it to our sponsor with an explanation of the course and recommendations for its improvement. Throughout the creation of the FSAP, we simultaneously collected data and made revisions to the IEMP. Fortunately, there was a mentor check-in meeting at the LTM that coincided with our time in London, allowing us to collect data easily from the program's mentors. We discuss each objective in more detail in the following sections.

3.1: Objective 1: Identify Primary Learning Outcomes for the FSAP's Curricular Design

Our first objective was to determine the desired learning outcomes for the FSAP. To do this, we conducted semi-structured interviews with educators at Greenwich UTC and learning officers at the LTM. We met with Jane Gordon, Deputy Principal of Greenwich UTC, David Sandell, a science teacher at Greenwich UTC, and David Houston, Learning Officer at the LTM, to determine their goals for the curriculum. Using our research, analysis of the IEMP's existing materials, and interviews with educators, we identified the learning outcomes. The most important learning outcome was proving to students that careers in STEM are interesting, impactful, and attainable. Additionally, Jane Gordon stressed, in an interview, the program should focus on developing students personally and professionally. Refer to 5.1.1: Finding 1 to see the four learning outcomes for the program. We worked to ensure each lesson in the FSAP met at least one learning outcome. After determining the learning outcomes, we strove to create hands-on projects relevant to the General Certificate of Secondary Education (GCSE) curriculum.

3.2: Objective 2: Review and Analyze GCSE Curriculum

Because most schools utilize the General Certificate of Secondary Education (GCSE) education system, we had to analyze it in order to understand its intricacies. We completed this objective by studying the GCSEs and Greenwich UTC's curriculum as well as conducting informal interviews with educators. This allowed us to not only prepare a challenging and engaging program for students but also construct a relevant syllabus teachers could use to reinforce complex GCSE concepts. In Appendix A we provide a synopsis of courses included in the GCSE.

First, we researched and analyzed Greenwich UTC's curriculum for year 10 and 11 students to determine how we could make the program most applicable to them. Greenwich UTC has two additional curricular requirements on top of the GCSE for their year 10 and 11 students: work experience and project work. After analyzing this school's curriculum, we then explored the curriculum of state schools and academies. Because both state schools and academies follow government-mandated curriculums, they both offer the GCSE. Thus, by tailoring our program to the GCSE, we ensured the FSAP was relevant to the majority of secondary educational institutions.

To further our understanding of the UK's education system, learn how and when material is taught, and identify gaps our project could fill, we conducted interviews with educators at Greenwich UTC, including Deputy Principal Jane Gordon, science teacher David Sandell, and engineering teacher Mike Floate. After reviewing and analyzing the GCSE, we began to develop an engaging curriculum.

3.3: Objective 3: Identify Best Approaches to the FSAP's Curricular Design for Year 10 and 11 Students

To form the FSAP's design, we analyzed the education methods identified in Chapter 2 of this report and conducted interviews with Engineering Ambassador Eric Wright. According to our research on teaching styles, the most effective style involves cooperative learning and encouragement of student interaction (Slavin, 2009). A project-based curriculum is the best method to ensure lessons are retained as students who have worked in such an environment are able to recall more information than students learning in a traditional environment (Id). Our research outlined ten key points critical to project-based learning; see Appendix D for a description of all ten points (PBL, n.d.). In creating our program, we followed the American National Academy Foundation's (NAF) four levels of project-based curriculum design: classroom activities, content standards, Habits of Mind, and self-directed learning. The NAF is a reputable non-profit educational organization focused on supporting young people's personal and professional development in the United States and thus was an appropriate model for our curriculum. Figure 4 illustrates these four levels.

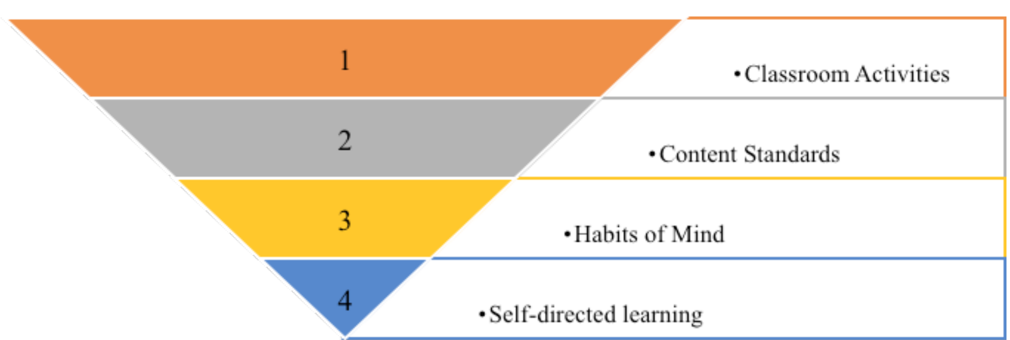

Figure 4: The four stages of developing a project-based curriculum (PBL, n.d.)

We began developing *classroom activities* to help students understand key concepts and provide a context for learning these ideas. Potential activities included the creation of a mechanical gearbox or an electrical circuit. Next we developed *content standards*, the necessary skills and concepts students should gain from the program. The content standards are the learning outcomes identified in 3.1: Objective 1. The third stage is called *Habits of Mind*, developed by Professor Art Costa and Dr. Bena Kallick, which is a set of behaviors "all people exhibit when they're acting intelligently" (PBL, n.d., pgs. 12-13). Professor Art Costa is a Professor of Education at California State University and Dr. Bena Kallick is a consultant who received her doctorate in education evaluation. See Appendix E for a list of the sixteen habits that constitute the Habits of Mind. The final stage outlined in Figure 4 is *self-directed learning* which allows educators to "create project opportunities to teach students to learn on their own in various different settings" (PBL, n.d., pgs. 12-13).

Next, we had to ensure the program met the four learning outcomes. We presented the activities to David Houston, Jane Gordon, and David Sandell so they could help us assess whether the activities we developed met the learning outcomes and requirements for the GCSE. Once we received their approval, we focused on the delivery, or *scaffolding*, of the program. Scaffolding refers to the "resources, tools, time, and training students need in order to succeed in project work" (PBL, n.d., pg. 22). Refer to Appendix F to view examples of scaffolds and their descriptions. We started scaffolding by estimating the resources, tools, and amount of time needed to complete each FSAP activity. For more complex sessions such as *Mixed Signals*, Session 3 in Appendix J, we tested the activity on ourselves. Oftentimes these self-tests yielded important results; upon completing the aforementioned activity we realized students would need additional information such as a chart of circuit symbols and explanations of each circuit component to be able to complete and understand the assignment. After determining a project-based curriculum would be the most effective format for the FSAP, we then focused on incorporating the learning outcomes into each session.

3.4: Objective 4: Develop an Education Program to Meet Learning Outcomes Identified in Objective 1

Our fourth objective was the development of the FSAP's prototype. This involved creating an initial design, submitting it for review to our sponsor, educators at Greenwich UTC, and IEMP mentors, and collecting their feedback to refine it. We used the expertise of numerous professionals to develop a curriculum from our initial ideas and research. Our primary feedback came from Jane Gordon and David Houston; we met with the latter regularly to discuss our progress and address his thoughts on our project. Additional feedback came from Eric Wright, IEMP mentors, and Martin Webber. Eric Wright, a signal engineer at the London Underground branch of TfL, generously donated his time to help us develop an activity related to signal engineering. The IEMP mentors, especially Aoife Considine, helped make suggestions about the structure of the program. Martin Weber, the STEM Sector Specialist at Oxford, Cambridge, and Royal Society of the Arts (OCR), met with us to ensure that the activities not only met the GCSE learning outcomes but also met its requirements to eventually accredit the program, or at the very least match teachers' ordinary curriculum. After deciding what to include in our program, we held an unstructured interview with Mike Floate, Jane Gordon, and David Sandell, educators at Greenwich UTC. In this meeting, those most directly involved with students critiqued our design.

Moreover, we compartmentalized the FSAP by activity; each activity is independent of concepts learned in prior activities so as to allow teachers flexibility in the classroom. In addition, the program culminates in a field trip to the LTM. This field trip functions as a capstone, connecting concepts learned throughout the course to real-world transportation engineering applications. Our focus was on developing the curriculum used during school sessions, while planning the logistics of the field trip were left to the LTM. Despite our emphasis on the in-school portion of the program, we heavily drew on ideas and materials for our curriculum from exhibits and materials from the LTM. We wanted to use resources from the LTM to give students an immediate connection with some of the exhibits and examples of transportation engineering. David Houston said the inclusion of the LTM's Engineering Handling Objects Collection in the FSAP would strengthen the connection between the curriculum and the LTM. Furthermore, the handling objects ensured students are immersed in real-world engineering applications and would preface students' visit to the LTM.

3.5: Objective 5: Pilot of Select Sessions of the FSAP

Due to our time constraints in London, we were not involved in the full implementation of the program. However, in order to test the effectiveness of the FSAP's curricular design at achieving the learning outcomes established in 3.1: Objective 1, we piloted select sessions of the prototype. In our pilot, we ran sections of the program separately with thirteen Worcester Polytechnic Institute (WPI) students and seven year 12 and 13 Business Technology Education Council (BTEC) Greenwich UTC students.

While we waited for the minors at Greenwich UTC to have their parents sign the necessary participation consent forms, refer to Appendix G, we piloted the four most challenging activities of the prototype with the third year WPI STEM students. Although the WPI students had more engineering training than the FSAP's target audience, testing the program with them was useful for two reasons: it gave us practice running pilots and focus groups and proved that the instructions provided in the student worksheets were usable. If the WPI students could not complete the FSAP activities, then we would have known that the younger Greenwich UTC students probably would have struggled as well.

Fortunately, the pilot and subsequent focus group with the WPI students went smoothly and provided us with valuable data which we used to improve the program before bringing it to the more relevant Greenwich UTC pilot. By the fifth week, we piloted the revised versions of the same four activities with seven year 12 BTEC students. At the conclusion of each activity, we held a focus group with participants to gain feedback on the session. The data compiled from running these pilots and focus groups allowed us to make revisions to our program; these changes are the focus of the 3.6: Objective 6.

3.6: Objective 6: Revise FSAP Based Upon Findings from Pilot

We revised the FSAP using focus groups and observations. A focus group allows students to comfortably express their ideas and expand upon their peers' opinions. Our research informed us that focus groups are conducted with group sizes of five to ten students, but ideally include six to eight participants (Krueger, 2002). A focus group enables the facilitator to easily direct the conversation towards specific topics, such as how students learn and what sort of activities they enjoy. The same consent form mentioned in 3.5, shown in Appendix H, for these focus groups. Students should be as comfortable as possible during the focus groups to aid open discussion (Krueger, 2002); thus, the reduced age difference between our team members relative to teachers better served our data collection needs.

After completing a partial pilot, we spoke with participants, whether they were WPI or Greenwich UTC students. Using this feedback, we began to revise the FSAP. The bulk of our changes focused on making our explanations clearer by condensing text or substituting it for diagrams. We reworked sessions where the students felt the instructions were unclear or we noticed students became disengaged; this mostly involved making the sessions' objectives clearer and breaking down larger tasks into a series of smaller, simpler ones that build up to a hierarchical goal.

3.7: Objective 7: Construct Recommendations for the FSAP's Further Curricular Development

Though we piloted particularly challenging elements of the curriculum with students, a complete pilot was unfeasible due to the availability of students at Greenwich UTC, who had GCSE exams, off-site work experience training, and term break during our short time in London. Therefore, we created recommendations for future curricular development of the materials. Because we only piloted select aspects of the program with WPI and BTEC Greenwich UTC students, we recommend the LTM, TfL, and Greenwich UTC run a full pilot with year 10 and 11 GCSE students, the FSAP's target audience. Thus we recommend the program be run at a state school. Based on our prior research, we know that Greenwich UTC and state schools both follow the same government-mandated curriculum; however, Greenwich UTC specializes in engineering and construction, so students there have an atypical interest in engineering that may have skewed our pilot's results. Some of the recommendations were modeled after revision methods in the IEMP. Because Greenwich UTC ran this program from November 2014 to July 2015, we had the opportunity to study the methods used in its revision, such as IEMP check-in meetings, and apply those that were successful to the FSAP. We include a full discussion of our recommendations in Chapter 6.

3.8: Objective 8: Review TfL Skills and Employment Strategy for Use in the IEMP

Before revising the IEMP, we consulted with TfL's Resourcing Manager James Lloyd to gather his input on the program based on its pilot. Mr. Lloyd asked that the revised IEMP include support for the BTECs, apprenticeship opportunities at companies, and the skills young people need to be employed. Specifically, he wanted TfL's Apprentice and Graduate employment schemes as well as the Confederation of British Industry's (CBI) Skills Survey (Breen, 2014) to be incorporated into the program. We also collected feedback from the LTM and Engineering Ambassadors through attendance at IEMP check-in meetings and the conduction of interviews.

3.9: Objective 9: Revise IEMP's Materials

We revised the IEMP Handbooks created by a prior WPI Interactive Qualifying Project team using feedback from TfL's Engineering Ambassadors, Greenwich UTC students, and our sponsor David Houston. We began this work in the first week and continued until we delivered the program to our sponsor. We started by thoroughly reading the existing handbooks to identify and eliminate redundant content. Once we made these revisions, we presented the revised copy to those Engineering Ambassadors who participated with the IEMP to ensure we addressed all of their concerns. Our final deliverables to the LTM included a revised set of handbooks in addition to the course material for the FSAP.

3.10: Objective 10: Orient Sponsor with the Finalized Curriculums

By our final week in London we had two thorough, vetted curriculums for our sponsor with a recommendation for their full implementation. We created the FSAP to inspire students to pursue careers in STEM. Additionally, we endeavored to make the IEMP self-contained and intuitive for the TfL mentors by revising and streamlining their mentoring guidelines and lesson plans so that mentors could look at a session's schedule and know exactly what they have to teach. Refer to Appendix N for a sample session from the IEMP. As the role of the program coordinator was well defined and worked effectively, we did not have to revise this; however, we added an additional mentoring position to the IEMP hierarchy. We discuss this in more detail in

Chapter 4. We concluded our time in London by formally presenting the FSAP and IEMP to representatives from the LTM, TfL, and Greenwich UTC; this presentation is outlined below.

3.11: Ethical Considerations

Every member of our team was committed to performing our work in a transparent and respectful manner, in full compliance of the rules and regulations set forth by the Worcester Polytechnic Institute's Institutional Review Board (IRB). While it was extremely unlikely anyone involved in our project would be harmed because of our work, we recognized the rights of our human participants and took the steps necessary to ensure their complete safety; we were especially proactive in this regard because many of our participants were children under the age of 18. A complete list of the considerations we made in order to protect our volunteers and copies of our consent forms and agreements can be found in Appendix H. Note that before each data collection method we have included a clause reminding participants of their rights.

Chapter 4: Findings

Through meetings, interviews, focus groups, and partial pilots we gathered data to design the Full Speed Ahead Program (FSAP) and revise the Inspire Engineering Mentoring Program (IEMP). We consulted with educational experts from Royal Greenwich University Technical College (Greenwich UTC), business professionals from Transport for London (TfL), and learning officers from the London Transport Museum (LTM) to develop the FSAP's learning outcomes and curriculum. Simultaneously, we analyzed the IEMP to suggest improvements to the program; most of justifications for these suggestions came from meetings with TfL Engineering Ambassadors and a review of the program's existing materials.

An alphabetical summary of the individuals who contributed to our findings and their affiliations are included in Table 6; please note the names of all students were kept confidential, in accordance with the ethical statements outlined in our methodology. A copy of these considerations is included in Appendix H.

Name	Organization	Title/Expertise	Data Collection Format(s)	Date(s)
Aoife Considine	Transport for London	Engineering Ambassador (IEMP)	● Meeting ● Interview	5/22/2015
Rachel Craddock	London Transport Museum	Learning Officer	Interview	5/20/2015
James Dawson	Transport for London	Engineering Ambassador (IEMP)	Meeting	5/22/2015
Michael Floate	Royal Greenwich University Technical College	Engineering Teacher	● Meeting ● Focus Group	6/3/2015 6/9/2015
Jane Gordon	Royal Greenwich University Technical College	Deputy Principal	Meeting	5/12/2015, 5/14/2015, 6/3/2015
David Houston	London Transport Museum	Learning Officer and our Sponsor	Interview	Continuous
Rachel	Transport for London	Engineering	Meeting	5/22/2015

Jackson		Ambassador (IEMP)		
James Lloyd	Transport for London	Resource Manager	● Meeting ● Interview	5/13/2015 5/22/2015
David Sandell	Royal Greenwich University Technical College	Science Teacher	● Meeting ● Focus Group	5/14/2015 6/3/2015
13 University Students	Worcester Polytechnic Institute	N/A	● Pilot Program ● Focus Groups	6/3/2015
Martin Webber	Oxford, Cambridge, and Royal Society of the Arts	Sector Specialist (STEM)	Meeting	6/3/2015
Eric Wright	London Underground	Engineering Ambassador	Interview	5/15/2015 5/21/2015
7 Year 12 & 13 BTEC Students	Royal Greenwich University Technical College	N/A	• Pilot Program • Focus Group	6/9/2015

Table 6: A summary of key sources of data

This chapter details the findings we reached through our data collection and how they shaped our deliverables. We begin by discussing the findings related to the FSAP; the second half of this chapter is reserved for the findings concerning the IEMP. We conclude this chapter with a discussion of the limitations of our work.

4.1: The Development of the Full Speed Ahead Program

The Full Speed Ahead Program was created to orient year 10 and 11 (ages 14 to 16) students with science, technology, engineering, and mathematics (STEM) concepts through a hands-on, project based curriculum. Over the past seven weeks, we gathered qualitative data from research and interviews with industry professionals to produce a finished program. Here we will outline the major steps we took to compose and test the FSAP, as well as discuss and justify the curriculum's learning outcomes, structure, and content.

4.1.1: Finding 1: The FSAP's Learning Outcomes

Our work began with the development of the FSAP's learning outcomes. Through interviews with Jane Gordon, James Lloyd, and David Houston, we identified four learning outcomes: (1) to inspire students to pursue a career in engineering; (2) to enable students to see the breadth and depth of engineering as a field; (3) to guide students to see the benefits of 'soft skills' in engineering careers; and (4) to empower students to have the confidence in their ability to pursue careers in engineering.

The idea to include support in the curriculum for the development of soft skills came primarily from an interview with Transport for London's (TfL) James Lloyd (Personal communication, May 13, 2015). Under his direction, we analyzed the Confederation of British Industry's (CBI) *Gateway to Growth* report and the graduate and apprentice schemes from TfL which further reinforced the importance of soft skills in the professional world (Breen, 2014). Jane Gordon also emphasized the necessity of soft skills in the FSAP as she felt they are "just as beneficial as technical skills" (Personal communication, May 14, 2015). For the purposes of this report and the FSAP, we adhere to the definition of soft skills as such abilities as public speaking, leadership, organization, teamwork, writing, and professionalism. Both reports analyzed the importance of soft skills and stated employers value soft skills more than technical skills especially with younger applicants who may not have developed their technical skills yet. Summaries of both reports are included in Appendix I.

Our desire to inspire students, illustrate the breadth of engineering, and boost participants' confidence through the FSAP derives from our previous research on the state of engineering in the UK. This research, which is included in Chapter 2 of this report, can be summarized by saying the UK is suffering from an acute lack of interest in science and engineering from the county's youth; we found this apathy may stem from misperceptions of the field. For example, the 2014 Public Attitude to Science Report found 18% of 315 students do not feel smart enough to become engineers (Castell, Charlton, and Clemence). Jane Gordon also provided qualitative evidence for this claim, reporting students do not realize the breadth of engineering and the impact engineers make on everyday life. The FSAP's learning outcomes address these concerns. Thus, we began to determine how to deliver this program in an engaging manner.

4.1.2: Finding 2: Project-Based Curriculums Effectively Convey STEM Concepts

Finding the right scaffolding, or delivery, of the program was the next step in the development of the FSAP. We chose a project-based curriculum with hands-on activities to better engage students when compared to lectures. For use in this report and the FSAP, a project-based curriculum is one in which students employ active learning and are encouraged to explore and experiment. This finding is derived from separate interviews with Eric Wright, Aoife Considine, and Ms. Harvey, as well as our background research.

Eric Wright, a TfL and Science, Technology, Engineering, and Mathematics Network (STEMNET) Engineering Ambassador and signaling engineer for London Underground, explained the importance of hands-on activities to us. He referenced an Inspire Engineering event he participated in at the London Transport Museum to teach young children about engineering. At this event, he was asked to stand at a static display called "Meet An Engineer" and found that children largely ignored him. Noticing this, he brought a model train kit with him the next day in the hopes that the presence of something more active would encourage children to approach him at the Meet an Engineer display. Through a dynamic set-up, he was able to gather an audience of young students who wished to play with the model train (Personal communication, May 15, 2015). Aoife Considine, a mentor for the IEMP, also found that hands-on activities were more engaging. She explained activities such as a bridge building exercise increased student participation compared to those that had students fill in answers on a worksheet (Personal communication, May 22, 2015).

The benefits of hands-on learning are well known to museums as well. Rachel Harvey, an explainer (museum employee who facilitates visitor exploration and learning) at the Science Museum showed us the *Launchpad* gallery, an example of the museum's dedication to hands-on STEM education. *Launchpad* explores light, materials, energy transfer, forces of motion, electricity, magnetism, and sound with exhibits geared towards students ages five to fourteen. It offers hands-on activities encouraging open-ended exploration, questioning, and discussion. For example, one exhibit focused on the phase change of water; Rachel Harvey first led us to the exhibit, and then showed us some additional props the museum has to support the display such as a model water molecule and polarized glasses. She informed us the museum had such objects close to many exhibits so explainers could provide more information to visitors who are exceptionally curious about the concepts covered in a specific display. She believed the combination of interactive exhibits, facilitating explainers, and additional resources was an effective way to teach young visitors about science and engineering (Personal communication, May 12, 2015).

Our background research supports these statements. According to the Philadelphia-Camden Informal Science Education Collaborative (PISEC) report on learning in museums, families had more in-depth discussions when exhibits were renovated to become more interactive (Borun, 1998). These concepts are even clear in college science courses; Richard R. Hake, a Physics Professor at the University of Indiana Emeritus, compared standardized test scores from

62 introductory physics classes and found students who learned in interactive environments outperformed their counterparts who attended traditional, lecture-based classes (Hake, 1998). This research is discussed at length in Chapter 2 of this report, but the evidence is clear: when teaching STEM concepts, hands-on activities are more engaging and effective than lectures.

4.1.3: Finding 3: A Flexible Program Best Complements Many School's Curriculums

Continuing the development of the Full Speed Ahead Program, we concluded, that the FSAP curriculum needs to be flexible and allow each session to run independently. This idea was formed from separate interviews with Jane Gordon, David Houston, and Rachel Craddock. Jane Gordon reported Greenwich UTC had more time and resources to dedicate to the program than most other schools as the UTC focuses heavily on engineering and construction; students at Greenwich UTC would have an entire week to dedicate to the FSAP and have relatively advanced equipment for use by their pupils. David Houston emphasized that the program ought to be flexible to accommodate a variety of schools and their individual resources. Therefore, we constructed a program not only to fit the schedule and resources of Greenwich UTC but also those of state schools.

Similarly, interviewees stressed the sessions should be independent but should also relate to a larger theme. Rachel Craddock informed us in an interview a curriculum should be "flexible so that teachers could pick and choose activities" from the program. We applied this knowledge to the FSAP; its flexible structure allows teachers to run the activities they find most relevant.

4.1.4: Finding 4: The Program Should Connect to Multiple GCSE Subjects

With the structure of the program established, we then developed its content standards. At the beginning of the development of the FSAP, David Houston, our sponsor, recommended the FSAP align with the General Certificate of Secondary Education (GCSE); this ensured the

FSAP related to students completing the GCSE. As the GCSE is the most popular education path in the UK, building the FSAP around it meant the new program would reach the largest possible audience.

Other professionals agreed with David Houston's specification, but contributed surprising data regarding which GCSEs should be highlighted. Initially, we thought the program should focus on STEM subjects exclusively, but after several interviews with Jane Gordon, David Sandell, and Martin Webber, we deduced the curriculum should not only cover transportation engineering but also link to GCSE subjects like English and history. This would make the FSAP a more balanced curriculum and benefit students in several subjects.

Jane Gordon especially wanted us to incorporate extensions to the "history of transport" so the program would connect nicely to the tour of the London Transport Museum (Personal communication, May 14, 2015). David Sandell agreed, adding it would be worthwhile to have students learn how transportation engineering challenges have been tackled throughout history (Id). An interview with Martin Webber, Sector Specialist (STEM) from Oxford, Cambridge, and Royal Society of the Arts (OCR), further supported this idea, saying it would be "nice to have the program fit within the GCSE history curriculum" (Personal communication, June 6, 2015). Refer to Appendix A for a description of the GCSE history subjects. The educators at Greenwich UTC also felt including writing portions in the curriculum would add breadth to the student's work and aid them in their English courses. Through the addition of subjects such as history and writing, and with the help of Martin Webber, we broadened the scope of the FSAP, making it possible to be accredited as a GCSE program.

4.1.5: Finding 5: Sessions Should Promote Soft Skills

In an interview with Jane Gordon, she requested that we include soft skills in each of the sessions, because they are as important as technical skills. Our response to this request for the inclusion of soft skill development was to have students form an "engineering firm" at the onset of the FSAP around which they will design a company culture encompassing a name, motto, code of conduct and logo to represent themselves and their goals for the FSAP. Our intention was to have students take a vested interest in the project and take ownership of their actions and roles within the company as well as improve their teamwork skills. To aid students in development of public speaking skills, a session was included where students would create a presentation to pitch their designs to the "Mayor of London" (the teacher), and explain why their company deserves the new tube line contract. Interspersed throughout the FSAP are smaller activities highlighting STEM subjects such as research phases which include the history of transportation in London as well as the opportunity for the teacher to have students write short essays recapping and discussing the topics learned in each activity. Session nine of the program, seen in Appendix J, has students create and present a pitch of their companies' deliverables to the teacher allowing them to practice their soft skills, one of our four learning outcomes.

4.1.6: Finding 6: Students Felt Accomplished After Completing Difficult Activities

One activity of the four piloted at Greenwich UTC on June 9, 2015 was *Mixed Signals*. Please refer to Session 3 in Appendix J for the complete activity. This activity had students construct a circuit using a breadboard and provided components, ultimately creating a signaling mechanism to switch between a green and red light-emitting diode (LED) depending on whether a sensor was in the light or dark. The goal of this activity was to demonstrate to students how a transport engineer might design a circuit to signal when a section of track was occupied by a train.

Although year 10 and 11 GCSE students have taken courses relating to basic circuitry, several of the concepts in the activity will not be introduced to students until their General Certificate of Education Advanced Levels (A-levels). This made the activity challenging to students as seen in the pilot done with the seven year 12 and 13 BTEC students who despite having taken circuitry classes were not familiar with the A-Levels. At the conclusion of the activity after about two hours, six of the seven students had constructed working circuits. All of the students in the focus group following the activity reported they had enjoyed it and had grasped the concepts involved in the construction of the circuit (Focus group participants, personal communication, June 9, 2015). Additionally, students reported the activity had enhanced their confidence to understand engineering concepts and encouraged them to pursue engineering related to the application of electrical devices in transportation engineering (Id). Despite the majority of students completing the circuit, one did not and another required considerable instructor attention. We discuss this observation in Finding 7.

4.1.7: Finding 7: Each Activity Needed to Cater to All Levels of Student Abilities

When piloting the program it quickly became apparent that some students excelled at certain activities while their classmates struggled. Generally this decreased the effectiveness of the FSAP because excelling students completed the assigned activity in very little time and then found there was little for them to do; at this point these students either attempted to help their peers, or, unfortunately, ended up talking and distracting everyone else. Those pupils working at a slower pace, however, were frustrated by their difficulty with the activity and were disheartened to see their peers race through a challenge which caused them to struggle. When we ran a partial pilot at Greenwich UTC, students were not placed into groups, and the drawbacks of different learning speeds were apparent. However, the WPI students who participated in a partial pilot were placed in groups, and a team mentality developed, demonstrating the benefits of learning in teams. A truly effective program would be flexible enough to adequately engage participants working at different paces.

In response, we structured the FSAP to include additional activities to challenge students who quickly completed the main activity. This "Above and Beyond" section was included only in the Teacher Handbook so students working slowly would not feel like they were missing out on another activity. Ideally, any given group of students would have both types of pupils, and the team members who grasp a certain concept would be able to explain it to everyone else.

4.1.8: Finding 8: Students Required Clear Objectives to Remain on Task

Mixed Signals and *Station Fixation* were two of the four activities we piloted at Greenwich UTC. Refer to Appendix J for a description of these two sessions and worksheets. *Station Fixation* had students design an underground tube station. The students worked individually on their station designs and then collaborated on choosing the location of their station. In both activities' pilots, students failed to remain focused during the sessions' research phases. Students required constant instructor input to keep on task and thinking critically about the activity. The student worksheet provided by the instructor consisted of guidance questions to help facilitate research, but clearly it was clearly not enough to keep students engaged.

This was especially apparent in the *Station Fixation* activity wherein students began researching tube stations online and then ended up talking about their favorite music artists. Once the students reached the design phase of the activity, they became less distracted and began to plan out their stations' designs. After the pilot of these activities, we ran a focus group with the students. In the *Station Fixation* focus group, we learned that students enjoyed the activity once they got into it, as evinced by some of the relatively detailed sketches they produced; copies of these designs are included in Figure 5. However, they stated that the research phase of the activity "took a while to get into" and was "boring" (Focus group, June 9, 2015).

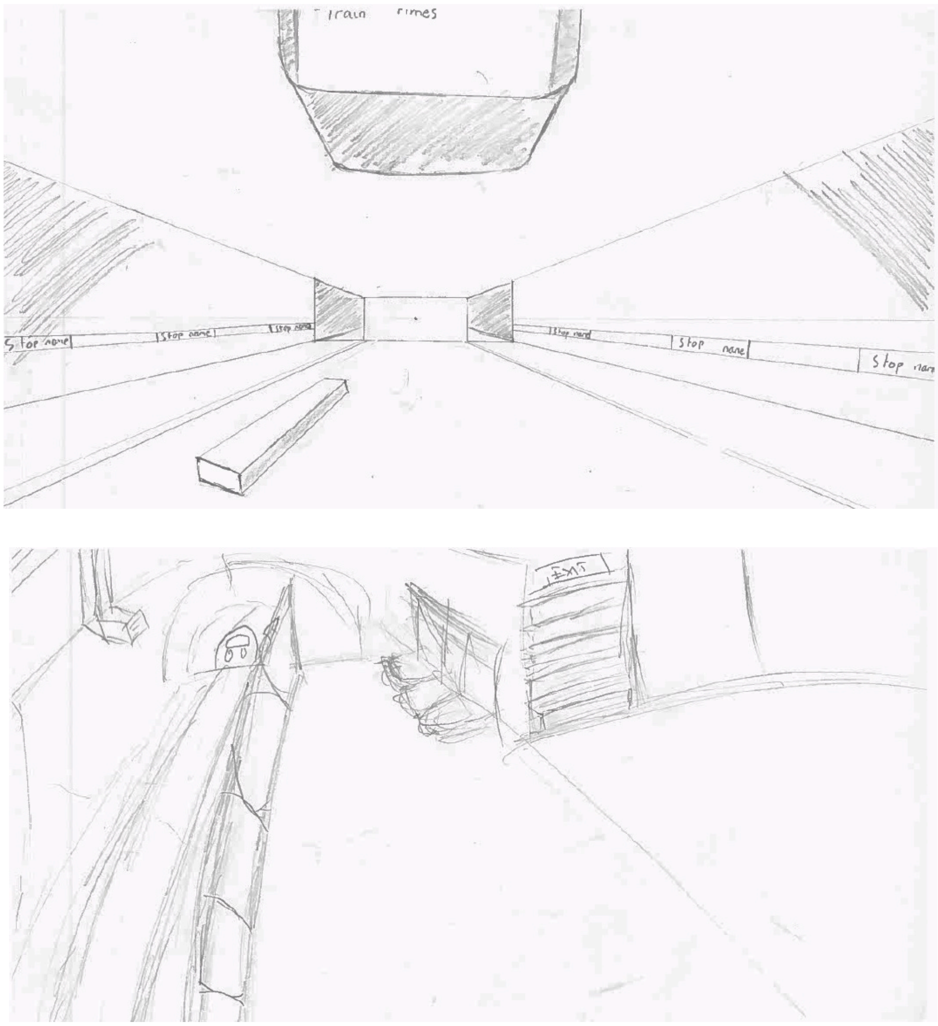

Figure 5: Sample student designs from the Station Fixation activity

In response, we reformatted the structure of these two activities. The original research questions in the student sheet were moved to the Teacher Handbook so the teacher could help prompt the students' research. We then incorporated smaller hands-on activities into the research phase to increase student engagement. We also included diagrams and photos of stations to foment student exploration. We applied this new structure to several other activities in the program, including *Business As Usual*, *Mind the Gap*, and *Tunnel Vision*.

4.1.9: Finding 9: Diagrams Conveyed Concepts to Students More Efficiently and Engaged Them Better than Text

During the pilot at Greenwich UTC, students generally ignored long blocks of text, even if they knew the writing contained crucial information that would help them complete the activity. For example, the *Mixed Signals* activity, Session 3 in Appendix J, contained a lengthy, text-based Resource Handbook. Students needed to use the ideas in this handbook to complete the activity, and although we told them all necessary information was included therein, they still avoided reading the relevant sections.

We anticipated this aversion to text, so we put several images and diagrams into long blocks of writing, even for the *Mixed Signals* activity, but it was clear we needed to replace even more text with pictures. This knowledge was useful as we revised the FSAP after the pilot program. We removed as much long text as possible, sometimes merely breaking up long paragraphs into multiple shorter ones. Also, we separated large activities into smaller parts so students are never asked to review too much information at once.

Additionally, our sponsor David Houston suggested we include pictures of exhibits at the LTM in the student worksheets to engage students. Not only does this remind students of the relevance of transportation engineering, but it also excites them about possibly visiting the museum. When asked how these pictures would enhance the student's experience at the LTM, David Houston explained "The way to engage youth groups is to give them a section of the museum before they come in…this gives them an ownership of the museum and they will actually curate the exhibits to their teachers" (Personal communication, June 11, 2015). Thus including pictures of the LTM benefited the FSAP twofold; it reduced the amount of text students must read and furthered their interest in the museum.

4.1.10: Finding 10: URLs Cannot Serve as Standalone Resources

A key part of generating the FSAP curriculum was creating a Resource Packet; this section has reference material that abets each lesson, but is not necessarily relevant enough to be included in the student worksheets or Teacher Handbooks. In reviewing the Inspire Engineering Mentoring Program (IEMP) materials, we found many of the included uniform resource locators (URLs) no longer functioned. Obviously, providing a link which may break over time reduces the long-term effectiveness of the FSAP. To solve this problem, we included URLs where we felt they would provide an additional resource, but always ensured other written material was prepared for students to use. If students wish to learn more about a concept, most sessions have written material in the Resource Handbook. However, a URL for content such as webpages or educational videos may also be included to complement this written material. In this way, we combined the flexibility and variety URLs allow but always ensure there is still relevant material should the links break.

4.2: Inspire Engineering Mentoring Program

Our work with the Inspire Engineering Mentoring Program (IEMP) involved revising the existing curriculum based on feedback from mentors and stakeholders participating in its pilot. Through an analysis of the existing IEMP curriculum and feedback from the program's coordinator, mentors, and students, we streamlined the bulky materials, restructured the program's schedule, and sparingly added necessary information and activities.

4.2.1: Finding 11: IEMP Student Handbook was Too Long

According to David Houston, Greenwich UTC IEMP mentees, and IEMP mentors, students were disinterested in the IEMP due to the size of the Student Handbook. The booklet, which students were expected to keep for six months to be used only once monthly, was sixty pages long; quite simply it looked like a textbook. Students were already off-put by the presence of another packet to complete, so the sheer length of the IEMP Student Handbook greatly inhibited their desire to participate in the voluntary program (Focus group participants, personal communication, June 6, 2015), a point separately made by both the mentors and participating students. Furthermore, Aoife Considine, Rachel Jackson, and James Dawson, all IEMP mentors, reported students seldom remembered to bring the booklet to meetings, or lost it during the first few sessions of the IEMP (Focus group participants, personal communication, June 6, 2015). We expected this problem would be exacerbated further when the program runs in full next year with ten monthly meetings instead of six. Clearly this challenge needed to be addressed.

4.2.2: Finding 12: The Curriculum Should Have a Flexible Design with Minimal Information

Rachel Craddock reported from her experience in facilitating programs similar to the IEMP, only the “bare essentials” needed to be included in resources given to mentors and mentees; she said more “flexible” programs were usually more successful than those with rigid curriculums. With this in mind, we streamlined both the Student and Mentor Handbooks as much as possible, and any vital material added to either Handbook was simplified and made easy to read through the use of charts and diagrams. We drastically reduced the material presented to students, limiting their materials to a worksheet per session. Upon hearing of our ambitious streamlining, Aoife Considine suggested we combine the Student Handbook and Mentor Handbook; this way, mentors could photocopy relevant session information for students and bring it to the meetings, ensuring students never lost their materials or were unprepared to for a session. Thus the Student Handbook was integrated into the streamlined Mentor Handbook as session worksheets. View Appendix J for the revised worksheets.

4.2.3: Finding 13: Goal Setting Helps Sustain Mentee's Motivation

Another area for improvement unanimously agreed upon by both mentors and stakeholders was the mentees' low level of motivation; they were reported as oftentimes being lethargic during meetings or not bothering to show up at all. Jane Gordon summarized the mentees' view of the program in saying that they generally felt the program was not worth their time (Personal communication, May 14, 2015).

To better engage students, we added an activity to the curriculum where they create their own code of conduct and goals for the IEMP. We hoped this would help the students take their participation more seriously. Setting goals at the start would allow students to communicate what they felt they would benefit from, and know that these views will be heard and taken into account by their mentors. Furthermore, goal-setting and considering consequences for their actions should help students feel they are being treated like professionals. Rachel Craddock also explained setting goals would help mentors grasp the individual concepts each student wanted to learn about and tailor their approach to fit their group of mentees (Personal communication, May 20, 2015). These interviews are further supported by the American National Academy Foundation's "Project-Based Learning" article, which discussed the importance of self-directed learning, allowing students to set the tone of the program and explore a different working environment than the classroom.

4.2.4: Finding 14: Mentees are More Focused and Willing to Engage in Larger Groups

We also found the mentor-mentee relationship worked better with a larger number of students in the group; simply having more peers at IEMP meetings made participating students more comfortable and more involved in the program. According to James Lloyd, James Dawson, Aoife Considine, and Rachel Jackson, students were less likely to join mentor meetings if only one other student was present because the atmosphere intimidated them (Personal communication, May 22, 2015). Similarly, late or unprepared (without their homework done) students would not join meetings because these faults would be easily recognized in a small setting. This resulted in many students choosing to avoid meetings, sacrificing their opportunity to work with their mentors (Id).

During one of the later sessions in the IEMP so few students showed up that the mentors decided to combine their groups to yield about five mentors and nine students in total. It quickly became apparent that students worked much better in this less structured environment. Using this serendipitous evidence, the mentors requested we alter the structure of the IEMP, which currently places three mentees to one mentor. Since it was clear students work better in larger groups and that on a given day some students will be absent from some groups we readily obliged. The group structure was changed to include two mentors to a group of six students. Students should benefit from the low-pressure atmosphere inherent in this structure, as well as the opportunity to hear from more than one mentor. Ensuring each student still receives individual attention from the mentors, we maintained the same mentor-to mentee ratio Overall this new format will improve the energy and environment of the IEMP.

4.2.5: Finding 15: Mentors Failed to Relate with Mentees' Learning Paths, Especially the BTECs

In speaking with James Lloyd, we learned the mentors' unfamiliarity with their particular students' educational paths inhibited full their immersion in the IEMP. As we discussed earlier in this report, students in the UK can participate in many different curriculums, and while this selection may be beneficial in catering to the variety of learning styles also analyzed earlier, it does mean there are many facets of the education system which an all-inclusive program like the IEMP must cover. Failure to relate to a particular learning path can place a barrier in the crucial mentor-mentee relationship.

James Lloyd explained that mentors were the most unfamiliar with the Business, Technology and Education Council (BTEC) curriculum. Therefore, he felt that a critical addition to the Mentor Handbook would be a brief outline of the BTECs, thus increasing the scope, effectiveness, and reliability of the IEMP. As we continued gathering opinions about this matter, we interviewed Rachel Craddock, who echoed James' Lloyd's concerns. Again, she stressed helping mentors better relate to their mentees would allow them to further tailor the program to their students.

4.2.6: Finding 16: Many Mentors Lack a Full Understanding of the BTEC Curriculum

In an interview, James Lloyd requested a section on the BTECs be included in the report (Personal communication, May 13 2015). As a team, we brainstormed many different ways to familiarize mentors with the BTECs. Ultimately we created a comprehensive summary of the BTECs and organized the information in a table. Included in the table are some of the courses required for the BTECs, which will help mentors relate to students' current situation, as well as possible opportunities for further education with the BTECs, which will help mentors advise students on important future decisions. Having a clear reference sheet that mentors may use ensures the mentor-mentee relationship will not be inhibited by a lack of understanding and ultimately ensures the IEMP is applicable to different types of learners. Please see Appendix K for the *BTEC Reference Sheet*.

4.2.7: Finding 17: Experienced Engineers May Not Have Enough Time to Serve as Mentors

Clearly reliability is vital in establishing a healthy and productive mentor-mentee relationship. Just as we considered what was included in each handbook, we also evaluated how mentors were paired with students. James Lloyd aptly explained senior engineers are oftentimes extremely enthusiastic about sharing their extensive knowledge, but simply by virtue of their advanced responsibilities cannot dedicate the amount of time needed to effectively participate in the IEMP; he said many senior engineers actually found participating in lengthy outreach programs stressful and quickly became just another item on a to-do list.

Eric Wright, a decorated engineer with a long and successful career, testified to this claim, saying he was surprised by the amount of time he had to dedicate to mentoring his students in other outreach programs. Despite his enjoyment of outreach programs and his belief in their importance, he found fully participating in them placed strain on his work schedule (Personal communication, May 15, 2015). Obviously, this makes it difficult for mentors to put students first. Even James Dawson, a relatively young engineer, said he only had time to review the IEMP lesson plan the day prior to the meetings (Personal communication, May 22, 2015).

4.2.8: Finding 18: In General, Students Better Relate to Younger Mentors than More Experienced Engineers

James Lloyd also brought up another concern with the age of engineering mentors. Age, or more so the experience associated with it, can simultaneously add strengths and weaknesses to mentors' ability to connect to students. He mentioned the experience of older engineers can actually be intimidating to students. He explained students find it easier to identify with younger engineers who recently graduated from an apprenticeship or university but struggle to envision themselves as older engineers who are several decades into their careers. Additionally, the length of time passed since university for many older engineers prevents them from recalling the steps they took to their current position (James Lloyd, personal communication, May 13, 2015).

To ensure an effective mentor-mentee relationship, we found it necessary to play off of the strengths of both young and experienced engineers. From this information, we developed a structure that would have an experienced “Senior Mentor” be in charge of the young “Junior Mentor” participating in the program. The Junior Mentors would then be the ones in direct contact with the students. This structure, outlined in Figure 6, has several advantages over the current setup.

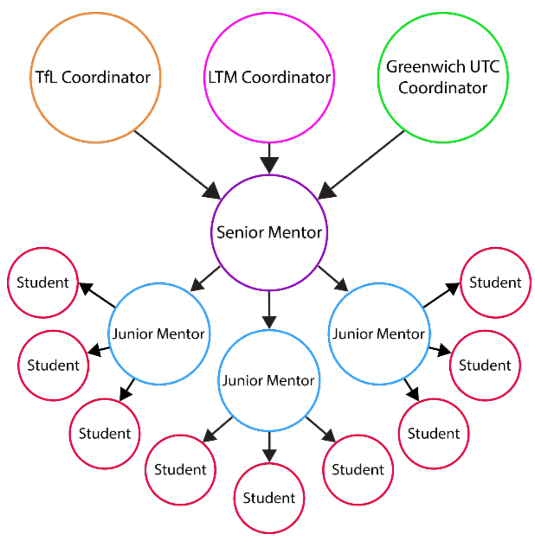

Figure 6: Revised structure of the IEMP

To begin, the structure enables older engineers to participate in the program and share their knowledge without having to commit as much time to it. Next, it allows younger, more relatable engineers to be in contact with students. Furthermore, it helps the Junior Mentors grow professionally as well, bringing them into contact with an engineer who they may want to emulate in addition to learning how to become a better mentor. Having a Senior Mentor liaison at Transport for London (TfL) who understands the program and technical concepts will be a great resource for Junior Mentors in need of teaching advice or lesson ideas. Thus Senior Mentors will complement the more logistics-oriented program coordinators, and Junior Mentors will have multiple sources of support; the Junior Mentor's increased confidence will greatly benefit the quality of the lessons given to the students. Jane Gordon, Rachel Craddock, David Houston, and Aoife Considine all felt this structure effectively uses the strengths of both young and old engineers and actually benefits both engineers and students.

4.2.9: Finding 19: Time for Tutoring should be added to each Meeting's Lesson Plan

With the logistics of the IEMP thus revised, we began to focus on the individual activities themselves. A common comment we received from mentors and stakeholders alike was that it would be beneficial to add a tutoring section to the mentorship curriculum. Having real engineers help students with their STEM coursework would add value for students and may even show them that engineers work in fields they are already studying. Indeed, if a mentor's work is related, it will illustrate for students the direct connection between their classroom lessons and problems facing the real world. This will not only make students more interested in the IEMP, but could also enhance their interest in their normal school lessons. Rachel Craddock, Aoife Considine, and Jane Gordon all enthusiastically stated in separate meetings tutoring time would be valuable for students and should be added to the mentorship meetings.

4.2.10: Finding 20: Some Activities are only Relevant at Certain Points throughout the School Year

Of course, for all the material we added, we considered the logistics of the activity and how it fit into students' busy schedules. Before we added anything to the IEMP, we thought about year 12 students' curriculums and made sure what we included was an effective and logical use of their time. For example, an activity exploring written personal statements for university applications was put into the IEMP, but we specified that it only be included at a certain point in the school year. The idea to include this session came from an interview with Aoife Considine wherein she mentioned the curriculum should include assistance for writing personal statements for university applications in addition to focusing on writing a curriculum vitae (CV). The discussion of CVs was undoubtedly valuable for future job applications, but for the many students planning to go to university it was not immediately relevant. While Jane Gordon agreed this was a worthwhile addition, we soon realized this activity could only be done before January, as after that point year 12 students will have already applied to university. Thus the importance of considering the perspective of the students is illustrated.

Another example of logistical considerations during activity development came into play when Jane Gordon requested the train carriage on Greenwich UTC's campus be incorporated into the program (Personal communication, May 14, 2015). We readily complied, but realized any activity focusing on the outdoor carriage would need to be in either one of the early or one of the late sessions. After all, an activity designed to take place in the train carriage during the winter would not be successful simply because of London's climate. We added activities to help ensure the IEMP maintains its applicability and general success.

4.2.11: Finding 21: Mentors want a Selection of Activities and Concepts to Use in Their Handbooks

When we interviewed David Houston about revising the IEMP he explained flexible, adaptable lesson plans are both more likely to be used by mentors, and more effective at engaging every student. He informed us that many of the mentors he spoke with before we arrived had different approaches to the IEMP and thus used the Mentor Handbook differently. Our own interviews verified this claim. Though Eric Wright was not involved in the IEMP, in other outreach programs he seldom used prepared teaching resources and instead provided anecdotes from his own work to inspire and engage students. On the other end of the spectrum, Aoife Considine felt the Mentor Handbook took a lot of stress out of preparing for her meetings and cited it as a great source of ideas and structure if she ever felt she needed something more to talk about with her students. Of course, neither method is "correct" because every mentor is different and what works well for one may be unsuccessful for another; nevertheless an effective Mentor Handbook should aid both styles.

In response, we ensured each session had plenty of activities for mentors to use as they saw fit, but prevented unused activities from detracting from the overall goal of the IEMP, to inspire and engage students in engineering and help them grow professionally and personally. We kept many of the "Alternate Sessions" already included in the program and even added some which may be substituted for another day's activity should the mentor decide the scheduled session would be unsuccessful. We included a surplus of activities in the Mentor Handbook to allow mentors to select activities ideal for each meeting while keeping the sessions relevant to the program's overall goals. Note that Aoife Considine, Rachel Jackson, and James Dawson all said the length of the Mentor Handbook is irrelevant and does not intimidate mentors (Personal communication, May 22, 2015). All mentors preferred having too much information to too little.

4.2.12: Finding 22: Written Reflections and Homework Were Seldom Completed

One section that may be cut out of both the Mentor and Student Handbooks, however, is any and all space for reflection or student homework assignments. Aoife Considine, James Dawson, and Rachel Jackson all said that these sections were never completed and simply added bulk to the packets. Aoife Considine said she was not concerned students never did the homework because the IEMP is a voluntary course and students have enough homework already (Personal communication, May 22, 2015). On the mentor's end, James Dawson said he did not have time to fill out any of the reflection sections, a concern Aoife Considine and Rachel Jackson echoed (Id). Aoife Considine poignantly ended any debate on including these sections by saying "If mentors didn't fill out the reflection section, then students definitely didn't" (Id) We cut out all space for reflection and homework assignments, reducing the bulk of the materials while making them leaner and more focused on the goals of the IEMP, student inspiration and professional development.

4.2.13: Finding 23: Check-In Meetings were Effective Revision Elements

While asking students and mentors to contribute written evaluations of the IEMP was not effective, regularly scheduled check-in meetings for mentors and stakeholders were. We attended one such meeting and found it was a sufficient way for program coordinators to gather mentor feedback and make improvements to the program. Therefore these meetings were left in the IEMP as a way for it to improve as time progresses. After all, most of the feedback we used to revise the IEMP came from comments made during these check-in sessions.

We used this model to propose a mechanism for improvement for the FSAP as well. Teachers obviously cannot be asked to attend regularly scheduled, off-site meetings during work hours, so we organized a way for a stakeholder from the LTM to reach out to these professionals to verbally gather their comments and hear their experiences. The intimate relationship between the LTM and Greenwich UTC will make it very easy for stakeholders to casually meet with participating teachers, and this model will later expand to other schools. In this way, both the IEMP and FSAP will continuously evolve and improve.

4.3: Limitations

As with any study there are always limitations. Due to our brief time in London, we were unable to fully pilot our program at Greenwich UTC because, like most schools, they were in the process of completing GCSE Exams from Monday May 4, 2015 to Friday June 26, 2015. Though this was not unexpected, it prevented us from gathering feedback on the entirety of the FSAP. To overcome this issue, we piloted select sessions of the program potentially difficult for students to understand or carry out: *Mixed Signals*, *Station Fixation*, *Time is of the Essence*, and *Rail Lines and Line Graphs*. These correspond to Sessions 3, 4, 7, and 8, respectively, and are described in Appendix J. By the end of our project, we had only tested these sessions on 13 Worcester Polytechnic Institute students and seven year 12 and 13 BTECs students. However, we gained valuable information from both of these groups. Additionally, the program was scheduled to be piloted in summer of 2016 with Greenwich UTC students, prompting us to include revision methods for program improvement after the conclusion of our report. We faced fewer obstacles while revising the IEMP because our time in London coincided with the pilot's last few sessions and we were able to attend feedback meetings set up to prepare for its implementation in September 2015. The programs, as delivered to the LTM, are described in the following chapter.

Chapter 5: Deliverables

This section includes a brief description of the structure and materials of the Full Speed Ahead (FSAP) program as well as the Inspire Engineering Mentorship Program (IEMP).

5.1: Full Speed Ahead Program

The FSAP has four learning outcomes: to (1) inspire students to pursue a career in engineering, (2) enable students to see the breadth and depth of engineering as a field, (3) guide students to see the benefits of soft skills in engineering careers, and (4) empower students to have confidence in their ability to be engineers in the future. All sessions worked to address the first learning outcome by showing students what engineering has accomplished and its prevalence. This learning outcome culminates in Session 10, wherein students visit the London Transport Museum (LTM) to see real-world examples of engineering on display. The use of sessions that inform students about specific applications of engineering accomplished the second learning outcome; the sessions on signaling and tunnels, for example, illustrate electrical and civil engineering respectively. Soft skills, the focus of the third outcome, are developed through small written and discussion activities included in most of the sessions; however, Session 9, Show Time, puts these skills on display when students present their rail line to their peers and teacher. The fourth learning outcome, to empower students and boost their confidence, is completed through sessions that allow students to see how relatively simple concepts have real-world applications. Sessions that address this in particular include *Mind the Gap* and *Rail Lines and Line Graphs*; we include a description of these activities below.

The FSAP consists of ten sessions, each designed to take a minimum of one hour. The sessions explore a multitude of activities, ranging from team-building exercises to bridge building. In the first session, *Business as Usual*, students are grouped by the teacher into mock transportation engineering firms which they will remain in for the duration of the program and compete for the tube line contract. The FSAP is comprised of two handbooks, a Teacher Handbook and a Resource Handbook. The teacher handbook includes an introduction detailing the project's goals and format used for the sessions. Also included is a letter which orients Transport for London's (TfL) Engineering Ambassadors with the FSAP. Each session in the Teacher Handbook, follows the structure listed in Table 7.

Section	Description
Introduction	Provides context for the activity and is read aloud to the students.
Concepts	Concepts that students will encounter in the activity.
Learning Outcome(s)	The goals that students will learn from the activity.
LTM Exhibit Connection	The LTM has exhibits that match up with the listed activities. Refer to Appendix M for a letter to the LTM program coordinator and list of objects used in the FSAP.
Research Phase	Students explore the concepts they will need to complete the activity.
Design Phase	Students collaborate in groups to create a novel design.
Build Phase	Models are produced. Note that all building materials should be provided by the school, not the London Transport Museum.
Recap/Discussion Phase	Students develop soft skills.
Above & Beyond	Options within each session to further challenge excelling groups.
Suggested Evaluation	Largely the selection of the "best" design is left to your discretion as the time and materials available to each class will greatly affect their output. In general, consider concepts such as strength, size, creativity, feasibility, environmental preservation, and cost (again, the relative "cost" of materials is left to your discretion).

Table 7: The structure of the FSAP Teacher Handbook

The Teacher Handbook consists of two parts. The first is made up of the teacher instructions for each session. This is followed by student worksheets intended for distribution to the class. In addition, we included a Resource Handbook should students need additional historical or technical information to complete an activity. These are all materials to help teachers engage students and immediately apply concepts learned, provide information, or promote discussion. A draft copy of the FSAP Student Handbook, which is the collection of pages for students within the Teacher Handbook, is available in Appendix J. Some parts of the sessions allow students to go further in depth if they are granted more time, and include additional challenges detailed in the "Above and Beyond" sections of the Teacher Handbook, though estimate times for each section of the sessions are listed in the handbook. Teachers have the option of using relevant artifacts housed in the London Transport Museum in many of the FSAP sessions. These details make the FSAP flexible and allow teachers to select which sessions to use. Below is a brief description of each activity and the pertinent concepts:

- **Session 1: Business as Usual (Learning Outcomes 1 & 3)-** Students are grouped together and form mock engineering firms which are tasked with developing a mission statement, logo, motto, and code of conduct. They are then set in a competitive negotiation game centered around trading for resources to meet contracts. This session sets behavior standards for the rest of the FSAP, and gives students a chance to practice communication and negotiation skills.
- **Session 2: Train of Thought (Learning Outcomes 1, 2, & 4)-** Students design and build a train and track. The train is the key part of the session, and students may be challenged to consider the propulsion and braking methods their train would use.
- **Session 3: Mixed Signals (Learning Outcome 1 & 2)-** Students build a light-sensing circuit that could be installed on their track as a simple signal. This activity challenges students' knowledge of circuits and encourages them to consider safety on rail lines. This activity introduces students to A-Level content.
- **Session 4: Rail Lines and Line Graphs (Learning Outcomes 1, 2, & 4)-** Students relate kinematics to rail line optimization, specifically addressing acceleration and headway, the time interval needed between trains to prevent collisions.
- **Session 5: Mind the Gap (Learning Outcomes 1, 2, & 4)-** Students will research some important elements of transportation and the history of bridge design. Then they will design and build a bridge across a small gap. The constructions are evaluated by the weight they can support, the cost of their materials, and the structure's weight.
- **Session 6: Tunnel Vision (Learning Outcomes 1 & 2)-** Students design and build a tunnel. This session is analogous to Session 5.
- **Session 7: Station Fixation (Learning Outcomes 1, 2, & 3)-** Students research, design, and build a tube station. They can design advertisements for their station to develop persuasive reasoning skills, or determine where to place signs to best inform passengers of important information.

- **Session 8: Time is of the Essence (Learning Outcomes 1 & 3)-** Students create a schedule for the construction of a project using a form of mathematical analysis. This is designed to target critical thinking skills and challenge students to consider a real-world application of mathematics outside of their experience with the subject.
- **Session 9: Show Time (Learning Outcomes 3 & 4)-** Students present their proposed train, rail line, station, and other components created over previous sessions to the teacher. The aim is to show students the value of communication skills in engineering.
- **Session 10: A Journey through Time (Learning Outcomes 1)-** The final session includes a visit to the LTM where students connect concepts learned in the classroom to London's history of transportation. This session summarizes the exhibits highlighted in each session again for reference.

Students in the UK use a variety of educational systems, but our goal was to address the standards of the General Certificate of Secondary Education (GCSE). Sessions are mapped to the GCSE standards in science, engineering, and history. Our program assumes students have the knowledge a year 10 GCSE student. Some topics serve as introductions to A Level concepts so as to challenge students and present a first glimpse of material they may see in the future.

5.2: Inspire Engineering Mentoring Program

The Inspire Engineering Mentoring Program (IEMP) was too structured and did not allow mentors the freedom to work with smaller groups, or change sessions if they wanted to adjust the material they used. We changed the IEMP to make the sessions work with different-sized groups, and added more content. Some of the major changes include:

- A new session that focuses on writing personal statements for university and college applications was included to aid students who want to pursue formal higher education. This session was scheduled for the December meeting as university applications are due every year on January 15th.
- A new session tasks students with creating a code of conduct and goals for the IEMP to encourage communication between mentors and mentees and to ensure the program is a valuable experience.
- The group sizes were made larger to reduce pressure on individual students. The size was changed from three mentees and one mentor to six mentees and two mentors.

- The mentors are now guided by Senior Mentors, who will have several years of mentoring experience, or be seasoned engineers. These engineers often have too many responsibilities to dedicate the time to attend meetings, but their knowledge will benefit the Junior Mentors.
- We condensed the Mentor Handbook material, removing unnecessary and repeated content.
- There was a large amount of duplicated information between the Student Handbook and the Lesson Plan Handbook. We eliminated the unused Student Handbook, and amalgamated the content into the Lesson Plan Handbook.

These changes address concerns made by participants in the IEMP's pilot, including stakeholders, mentors, and mentees. While the pilot was a success, the revisions we made, outlined above, should greatly improve the effectiveness of the program and enhance the students' experiences. Recommendations for the further development of the FSAP are included below.

Chapter 6: Recommendations

Cognizant of the limitations of our work, we wanted to offer recommendations for the continued development of the Full Speed Ahead Program (FSAP). Each recommendation describes an aspect of the program beyond our capabilities or too time intensive to complete during our tour. Given our success in improving the IEMP we believe the recommendations and revision methods already in place are sufficient for the continued development of the program.

6.1: Recommendation 1: Run a Full Pilot of the Full Speed Ahead Program

Due to timing conflicts with GCSE exams, we were unable to run a pilot of the FSAP in its entirety nor pilot all of its sessions individually with Royal Greenwich University Technical College (Greenwich UTC) students. We recommend a pilot of the program be performed wherein 20 to 30 year 10 and 11 students participate in the program from beginning to end and that their feedback be collected in focus groups by the London Transport Museum (LTM) coordinator after each session. To encourage an open dialogue about each session, the teacher should not be present and students should feel as comfortable as possible. The best approach is to run a separate focus group for each student group, or "company" as they are known within the program, to gain a better perspective on each group's experience. One struggling group might feel intimidated to share in a focus group with excelling ones. As student companies should include between four to six students, they would be suitable in size for a focus group (Krueger, 2002).

Furthermore, the program's intention is to inspire students not already interested in STEM to pursue such fields, thus a pilot at a state school is most beneficial. Greenwich UTC students already have in an interest in engineering and are not representative of the greater United Kingdom (UK) year 10 and 11 student population. Similar to the IEMP, we advise the

LTM run check-in meetings with involved teachers as an alternative perspective. Just as the program is meant to inspire students, it must also allow teachers ease of use in order to gain widespread adoption. David Sandell, a science teacher at Greenwich UTC, could not have stressed this more (Personal communication, June 4, 2015).

6.2: Recommendation 2: Extend FSAP Material to an Interactive Medium

This recommendation stems from 4.1.8: Finding 8 wherein students were most engaged by activity materials involving diagrams, such as the FSAP's *Time is of the Essence*, *Mixed Signals*, and *Rail Line and Line Graphs* activities. Please refer to Sessions 3, 6, and 7 in Appendix J to view the complete activities. Our literature review, found in Chapter 2, on the design of interactive museum displays also mentioned the benefits of engaging an audience using interactive resources and their benefits on learning. Similarly, interactive resources support the learning styles of more students than a static resource, such as worksheet, which happens to be the format of our current materials. We have several recommendations for possible interactive resources. The first is a web resource hosted by the LTM where students can navigate between web pages with short videos explaining the concepts of each activity. The web pages might also include interactive software where students could test their understanding of the concepts from these videos. The second is a computerized version of our additional resources and student worksheets, such as a portable document format (PDF), where students can search through concepts using link-based text allowing them to quickly jump between connected sections of a document. Both of these possibilities would aid student engagement throughout the program.

6.3: Recommendation 3: The LTM Should Provide an Orientation to FSAP Instructors

As discussed in 5.1.7: Finding 7, the program relies heavily on teacher involvement to keep students on task and thinking about possible obstacles, connections, and concepts in each session. The program was designed to cater to a variety of different teaching styles; however, this approach means a student's experience is highly dependent upon the teacher's involvement in the program. To ensure teachers understand the learning outcomes of the FSAP as well as the intricacies of the program, we recommend the LTM run an orientation which teachers can attend to learn about each session's concepts and objectives as well as have an opportunity to ask questions of the program's coordinators. Moreover, the orientation should invest teachers in the program. Enthusiasm is contagious and enthusiastic teachers are more likely to inspire enthusiastic students. Though the program was designed to encourage students to work through activities as autonomously as possible, an instructor will inevitable have to clarify concepts for struggling students.

6.4: Recommendation 4: Certify the FSAP as GCSE Curriculum through Oxford Cambridge and Royal Society of the Arts

During our time in London, we were approached by Martin Webber, Sector Specialist for Oxford, Cambridge, and Royal Society of Arts (OCR). He was interested in having our program accredited as a GCSE curriculum. Unfortunately, he made contact with us relatively late during our stay in London and scheduling a program accreditation meeting was unfeasible. To broaden the availability and incentives of GCSE schools to use the program, we recommend the LTM have the program accredited. In order to accredit the program, it needs to map to the learning outcomes and curriculum of year 10 and 11 GCSE students. The mappings are detailed in

Appendix L. Though the science and mathematics areas were mapped to the GCSE, the history sections remain to be done.

6.5: Recommendation 5: Revise photos and handling objects from FSAP's materials

Because our findings indicated students respond better to diagrams and photos when compared to text, we sought to include photographs of the LTM in the program's materials. Furthermore, David Houston requested we include photos of relevant exhibits so when students visit the museum they are already excited and knowledgeable about some of the materials. We found the LTM did not have high-resolution photographs of their current exhibits suitable for our purposes. Thus we photographed the exhibits ourselves, but our photography skills were limited and the images were not of professional quality. Therefore we recommend the LTM have professional photographs taken of their exhibits for inclusion in the FSAP's materials.

Additionally, we incorporated several of the museum's handling objects in the curriculum. Following our interview with LTM curator, Tim Shields, he informed us the requested handling objects would have to be reviewed by a curator as to whether or not they could be included (Personal communication, June 15, 2015). Sadly, we were only able to meet with him in the final weeks of our time in London and the curators were too busy to review our list of handling objects. We suggest that the LTM program coordinator have the recommended list of handling objects, included in our deliverables, reviewed by the curators for inclusion in the program.

The reviewed objects should be gathered and made easily accessible for distribution to Engineering Ambassadors visiting schools as part of the FSAP. A place should be designated for the objects, laminated sheets from the Engineering Objects cataloging project with information on the objects, and an inventory list with the objects organized by session.

Chapter 7: Conclusion

Regardless of these recommendations, at the end of our time in London we submitted two programs to the London Transport Museum (LTM): the new Full Speed Ahead Program (FSAP) and the revised Inspire Engineering Mentoring Program (IEMP). These programs represent the completion of our project's main goals, to inspire year 10 and 11 United Kingdom students to pursue engineering by developing a multi-disciplined, engineering-centric, project-based curriculum culminating in a tour of the LTM and to streamline and improve the IEMP's materials based on the feedback of the program's stakeholders. The development of these deliverables was the result of a synthesis of the concepts contained in existing literature, the experience of industry professionals, and our own creativity. Perhaps our greatest achievement was facilitating a constructive dialogue between students and teachers from Royal Greenwich University Technical College (Greenwich UTC) and from engineers and businesspeople from Transport for London (TfL) alike. We are confident both the FSAP and IEMP will be successful.

Over the past seven weeks, we have collected qualitative data from a series of interviews, meetings, focus groups, and pilots. Each method yielded exciting information that enhanced the effectiveness of our deliverables. Through all of our research, our most important finding was the necessity of allowing for flexibility within the programs. Education cannot and should not be restricted to set lesson plans and concept checklists. Everyone from representatives of the Science Museum to TfL's Engineering Ambassadors agree what works well for one student is not necessarily optimal for another, so an ideal curriculum should be agile enough to adapt to many different kinds of learners. The FSAP was designed to be as modular, and thus versatile, as possible, and the IEMP now has more opportunity for mentors to tailor the curriculum to their specific group.

As we discussed in Chapter 2, the UK has a dearth of engineers. Already the growth of the nation is being inhibited by a shortage of critical thinking STEM professionals, from mechanical engineers to mathematicians. Unfortunately, many UK students are shrouded in misconceptions about STEM fields. Twenty-four percent of the 510 youth participants in the 2014 Public Attitudes to Science (PAS) Survey felt their experience in school made science unappealing and 18% of the 315 youths from a booster survey felt they were not smart enough to understand engineering (Castell, Charlton, & Clemence, 2014).

We believe this project can inspire students to pursue engineering education and perhaps a career in engineering. A career in STEM is mutually beneficial; it can empower a person and affect millions more. This project will in some small way alleviate the challenges facing STEM education in the UK.

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Appendices

Appendix A: Educational Resources

Key Stage	Science	Math
1	• Working scientifically • Plants • Animals (including humans) • Everyday materials	· Number and place value · Addition and Subtraction · Multiplication and Division · Fractions · Measurement · Geometry
2	• Seasonal changes • Living things and habitats • Rocks • Light • Forces and magnets • States of matter • Sound • Electricity • Properties and changes of materials • Earth and space	· Same as above (more advanced) · Statistics- interpret graphs · Decimals
3	• Working scientifically • Biology • Chemistry • Physics	· Work mathematically- develop fluency, reason mathematically, solve problems · Subject content- number, algebra, ratio and rates of change, geometry and measures, probability, statistics

Table 8: National Curriculum (Department for Education, 2014)

	Science A (4405)	Science B (4500)	Biology (4401)	Chemistry (4402)	Physics (4403)
Topics covered	• Chemistry • Physics • Science	· Chemistry · Physics · Science	· Human biology · Organisms · Evolution · Environment	· Nature of substances and how they react · How chemistry is used in business and industry	· Use and transfer of energy · Waves, radiation, space · Application of Physics

				· How our use of raw materials affects the environment	
Benefits	• Subjects taught separately	· Subjects integrated · More applications	· Deeper focus on details in the subject · Can count as a Science component for the English Baccalaureate	· Deeper focus on the details in the subject · Can count as a Science component for the English Baccalaureate	· Deeper focus on the details in the subject · Can count as a Science component for the English Baccalaureate

Table 9: General Certificate of Secondary Education: New Science Component (AQA, 2014)

	Additional Science (4408)	**Additional Applied Science (4505)**	**Further Additional Science (4410)**
Topics covered	Biology (Unit 2) Chemistry (Unit 2) Physics (Unit 2)	Safety procedures Exercise and the Human Body Materials Science Food Science Selective Breeding	Biology (Unit 3) Chemistry (Unit 3) Physics (Unit 3)
Benefits	Combine with Science A and B to get a credit for English Baccalaureate	Vocational approach Integrates all three subjects	Combine with Science A and B to get a credit for English Baccalaureate

Table 10: GCSE Science Curriculum (AQA, 2014)

	Electronics (4430)	**Environmental Science (4440)**	**Human Health & Physiology (4415)**
Topics covered	Electrical Safety System Design Information system Processing Practical skills and process	Environmental Issues Environmental Management Issues	Cells, Cell Org., Cell Processes Nutrition Physical & Chemical Breakdown Blood & Circulatory System Gas Exchange Excretion Nervous System Muscles, Bones, and Movement Human Reproduction, Growth and Development

Table 11: Specialized Subjects (will be removed from GCSE curriculum in 2018) (AQA, 2014)

	Mathematics A (4360)	**Mathematics B (4365)**	**Mathematics (8300)***
Topics covered	Statistics and Number Number and Algebra Geometry and Algebra	Number and Algebra Geometry and Measures Statistics and Probability	Number Algebra Ratio, rates of change Geometry and measures Probability Statistics

Table 12: The GCSE Mathematics Curriculum (AQA, 2014)
Note: Will begin teaching in September 2015

	History A	History B
Studies In Development	• Medicine Through Time • Media & Mass Communication Through Time	• International Relations • Origins of the First World War (1890-1914) • Peacemaking 1918-1919 and the League of Nations • The Origins of the Cold War 1945-1960 • Crises of the Cold War and Détente 1960-1980
Enquiries In Depth	• The American West (1840-1895) • Britain (1815-1851) • Elizabethan England (1558-1603) • Germany (1919-1945)	Section A: • From Tsardom to Communism: Russia, 1914–1924 • Weimar Germany, 1919–1929 • The Roaring 20s: USA, 1919–1929* Section B: • Stalin's Dictatorship: USSR, 1924–1941 • Hitler's Germany, 1929–1945

		• Depression and the New Deal : The USA, 1929–1941* Section C: • Race Relations in the USA, 1945–1968 • War in Vietnam, 1954–1975 • Britain: The Challenge in Northern Ireland, 1960–1999 • The Middle East, 1956–1999

Table 13: GCSE History Curriculum (AQA, 2014)

Engineering	Science & Technology
Aeronautical	Applied Science
Building Services	Environmental Sustainability
Electrical Electronic	Dental Technology
Manufacturing	Information Technology
Mechanical	Land-based Technology
Operations and Maintenance	Vehicle Technology
	Sport and Exercise Sciences
	Pharmaceutical Science

Table 14: BTEC Nationals (Pearson, n.d.)

Electrical Electronic	**Mechanical**	**Applied Science**
• Health & Safety • Communications • Mathematics • Industrial Plant and Process Control • Applications of Electronic Devices and Circuits • Further Mathematics • Engineering Drawing • Properties and Applications of Engineering Materials • Engineering Design	· Health & Safety · Communications · Mathematics · Engineering Primary Forming Processes · Welding Technology · Mechanical Principles and Applications · Business Operations · Engineering Design · Applications of Thermodynamic Properties	• Fundamentals of Science • Working in the Science Industry • Scientific Investigation • Perceptions of Science • Mathematical Calculations • Informatics for Science • Science in the Workplace • Physiology of Human Regulation • Biochemistry • Microbiological • Chemistry • Genetics and Genetic Engineering

Table 15: Example subjects with topics covered (Pearson, n.d.)

Science	Design & Technology
Biology Chemistry Physics	Food Technology Product Design Engineering Mathematics

Table 16: GCE A-Levels (Pearson, n.d.)

Chemistry	Engineering	Mathematics
• Atomic Structure and Periodic Table • Bonding and Structure • Redox I • Inorganic Chemistry and the Periodic Table • Formulae, Equations and Amounts of Substance • Energetics • Kinetics • Equilibrium • Acid-Base Equilibrium • Transition Metals • Kinetics II • Organic Chemistry • Modern Analytical Techniques	· Engineering Materials, Processes, Techniques · Role of the Engineer · Principles of Design, Planning, and Prototyping · Applied Engineering Systems · Engineering Environment · Applied Design, Planning, and Prototyping	· Core Mathematics (Algebra, Calculus, Geometry) · Further Mathematics (Series & Sequences, Matrices) · Mechanics (Modelling, Kinematics, Relative motion) · Statistics · Decision Mathematics (Algorithms)

Table 17: Topics Offered in A-Levels (Pearson, n.d.)

STEM Ambassadors	STEM Club Program	Schools STEM Advisory Network
Network with over 27,000 volunteers (civil engineers, energy analytics, game developers, marine biologists, etc.) "who help deliver STEM curriculum and raise awareness about STEM careers"	Program that aims to help secondary schools establish and maintain STEM clubs.	Offers guidance to high schools and colleges to help motivate students to study and pursue STEM careers in the future

Table 18: STEMNET's Resources for Students & Teachers (STEMNET, 2015)

Appendix B: Discussion of Sponsor and their Affiliates

B.1: The London Transport Museum (LTM)

Our official sponsor, the LTM, is a charitable organization housing 450,000 artifacts illustrating 200 years of London's transportation history and facilitating outreach programs to 100,000 students annually (LTM, 2014). The information stored at the LTM is key in helping it complete its goal, "to conserve and explain the history of London's transport, to offer people an understanding of the Capital's past development and to engage them in the debate about its future" (LTMa, 2014, pg. 1). The museum's success is evinced by the statistics reported in its 2013/2014 Yearbook: 384,093 people visited the LTM, 26,235 of them schoolchildren on field trips; the organization's website received 1,215,079 visitors; and 160 volunteers logged 25,000 hours of work for the museum (LTMa, 2014). Families, students, researchers and adults all benefit from the practical knowledge and skills they receive when getting involved at the LTM, either through mentorship programs, volunteer work, or simply touring the exhibits (Id). As an authority on London's public transportation history (LTM, 2014), the LTM often collaborates with the organization responsible for running that infrastructure today, Transport for London (TfL, n.d.).

B.2: Transport for London (TfL)

The modern face of public transport in London, TfL, is the non-profit government body responsible for safely getting Londoners to their destination year round (TfL, n.d.). TfL has three branches, Surface Transport, which operates everything from busses to bicycles to gondolas, Rail and Underground (the latter is more often called "the Tube"), which is responsible for running the city's trains and subways, and Crossrail, the new rail line discussed above (TfL, n.d.). An average week in 2014 saw 24.3 and 46.2 million passengers utilize TfL's Underground and bus network, respectively (TfL, 2014). To keep up with this demand, the company employs 25,000 people, including civil, mechanical, and electrical engineers, a perfect source of talent for STEM education programs such as Greenwich UTC (TfL, n.d.)

B.3: The Royal Greenwich University Technical College (UTC)

A university technical college is a brand new education philosophy in the UK where students attend a free secondary school sponsored by major corporations and universities to develop technical and professional skills (Eatherden, 2015). Representing an investment of 10 million pounds, the Royal Greenwich UTC opened in 2013 with state-of-the-art facilities conducive to hands-on learning like collaboration areas, design studios, laboratories, and computer-aided manufacturing zones (Greenwich UTC, 2015). The school, which opened in 2013, is capable of accepting 600 students from ages 14 to 18, emphasizes STEM education and offers certifications in both the BTECs and GCSE's (Greenwich UTC, 2015). The Greenwich UTC is supported chiefly by the University of Greenwich and Transport for London (Eatherden, 2015), and the latter is currently involved in a mentorship program for 60 year 12 students. In this collaborative effort real engineers answer student's questions about their work, demystifying the field and perhaps guiding them towards a career in STEM (UTCNews, 2015).

Appendix C: Philadelphia/Camden Informal Science Education Collaborative (PISEC)

Characteristic	Description
Multi-sided	Family can cluster around the exhibit
Multi-user	Interaction allows for several sets of hands and bodies
Accessible	The exhibit can comfortably be used by children and adults
Multi-outcome	Observation & interaction are sufficiently complex to foster group discussion
Multi-modal	Activity appeals to different learning styles and levels of knowledge
Readable	Text is arranged in easily-understood segments
Relevant	The exhibit provides cognitive links to visitor's existing knowledge and experience

Table 19: PISEC's Seven Characteristics of Family-Friendly Exhibits (Borun, 1998)

Appendix D: Characteristics of Successful Project-Based Learning Programs

In the Classroom	At School	In the Community
• Respectful learning environments • Personalized teacher-student relationships • Productive peer relationships • Transformed teacher roles • Intensified teacher engagement and commitment	· Supportive school structures · Professional collaboration · Administrative report	· Parent involvement · Community partnerships

Table 20 (PBL, n.d.)

Appendix E: Habits of Mind

Habit of Mind	Definition
Persisting	Ability to try multiple ideas to solve a problem and not give up.
Managing impulsivity	Thinking before you act. Ensuring that students do not just simply shout out an answer.
Thinking flexibly	Broadening your mind to multiple solutions that may not seem apparent to the student at a first glance.
Metacognition	Ability to plan a strategy for producing what information is needed.
Striving for accuracy and precision	Ensure that students take time with the assignment and put more than a hundred percent of themselves into it.
Questioning and posing problems	Knowing how to ask questions to fill in the gaps about what students know and what they don't know.
Applying past knowledge to new situations	Being able to call upon previous knowledge and experience to help approach new problems
Gathering Data through all senses	Being able to absorb information through various methods: gustatory, olfactory, tactile, kinesthetic, auditory, and visual.
Creating, imagining, and innovating	Ability to generate original ideas and approach problems differently.
Responding with wonderment and awe	Delighting in making up problems to solve on their own.
Taking responsible risks	Being able to step outside their comfort zone for educated risks.
Finding humour	Ability to perceive situations from an original point of view. Playful when interacting with each other.
Thinking interdependently	Ability to justify ideas and to test the feasibility of solution strategies on others.
Learning continuously	Ability to always strive for improvement, always growing, learning, modifying, and improving themselves.

Table 21: Habits of Minds and definitions (Costa, n.d.)

Appendix F: Project Delivery

Scaffold	Description	Examples
Structure	Critical organizing features of the project to determine who does what and when	Students split into project teams or groups
Content	Any classroom activity that covers the foundational topics, concepts, and standards that students need to know for the project	Interactive lecture on customer service
Training	Explicit skill-building for students in group work and all required production areas	Modeling of key steps in creating PowerPoint presentations
Expertise	Professional-level training and consultation provided by outside experts or adults in the community	Teacher informally interviews each student team during project work days
Overnight	Structured times for teachers to meet, motivate, and mentor student teams	Teacher informally interviews each student team during project workshops
Documents	Handouts to help explain and organize project	Project descriptions and calendars
Tools	The technological resources necessary to produce required products	Computers, software, cameras, video
Time	In-class opportunities for students to meet, produce, exhibit, and evaluate	Designated 'project days'

Table 22: Types of project scaffolding (PBL, n.d.)

Appendix G: Full Speed Ahead Permission Slip

Parent/Guardian Permission Letter

Dear Parent/Guardian:

Your child has been asked to participate in a pilot of the “Full Speed Ahead” programme at Greenwich UTC. The project, sponsored by the London Transportation Museum (LTM), includes engineering activities that will inspire students to further their education in Science, Technology, Engineering, and Mathematics (STEM) fields. This is a collaborative project between the London Transport Museum and Worcester Polytechnic Institute (WPI), and your compliance is greatly appreciated.

In the programme, your child will run a portion of the “Full Speed Ahead” programme with a small group of their peers; they will then be placed in a focus group with several other students and an adult WPI student facilitator. The purpose of the subsequent focus group is to gain feedback from your son/daughter about the program. The identities of all participating students and teachers shall remain confidential, and there is no anticipated risk to participants. For more information, to receive a copy of the finished report, or to contact the WPI facilitators for any reason, please email ltm@wpi.edu.

Thank you for your time. We hope this programme will be of great benefit to your child.

Sincerely,

The WPI LTM Team
Lauren Baker
Casey Broslawski
Cameron Crook
Shannon Healey

I give permission for my child, ___________________________________, to participate in the ‘Full Speed Ahead’ Programme at Greenwich UTC. I understand the nature of the school’s efforts and reserve the right to withdraw my child from the programme at any time.

____ ____________________
Parent/Guardian Signature Date

Permission form adapted from The Maryland Mentoring Partnership, *Vision to Reality Mentoring Program Development Guide*.

Appendix H: Review of Ethical Considerations

We will mitigate the possibility of harm to participants involved with our work by employing the following axioms:

- Receive written consent from all participants under the age of 18 and their legal guardian before including them in any interviews, surveys, focus groups, studies, etc.
    - Note: We will include copies of our consent forms and participation agreements once we have more information about these important documents
- Remind participants any involvement in our work is entirely voluntary
- Comply with all requests for confidentiality and anonymity.
- Adhere to all local laws and each organization's code of conduct
- Restrict our work with participants to safe, professional, comfortable atmospheres
- Share a copy of our finished report with interested parties

In short, we will make every effort to conduct our work in a safe, respectful manner and will always place a participant's health and safety above our project.

Appendix I: Gateway to Growth and Transport for London Graduate & Apprentice Schemes

Gateway to Growth by CBI and Pearson

The Confederation of Business Industry (CBI) and Pearson published a report in 2014, Gateway to Growth, which discusses skills that are imperative for young people to have in order to be employable. Businesses want young people who are "rigorous, rounded, and grounded" (CBI,45). They want employees who not only know the skills and knowledge necessary for the job, but people who embody the attitudes and behaviors needed for success in both professional and personal development (Ibid).

Table 1 includes a pictorial representation of the attitudes and skills that businesses feel that school leavers lack. These areas include **teamwork** (17%), **basic numeracy** (18%), **problem solving** (24%), **communication skills** (25%), and **attitudes towards work** (24%) (CBI, 8). Specifically, employers have mentioned that they are not satisfied with graduates' **technical skills**. CBI implores that all of these are "essential skills for effectiveness in life". The report also suggests that perhaps the lack of skills are from an "undue emphasis on GCSE grades (or equivalent) and school leagues table risks distracting attention from the need to equip every young person adequately with these capabilities" (CBI, 48).

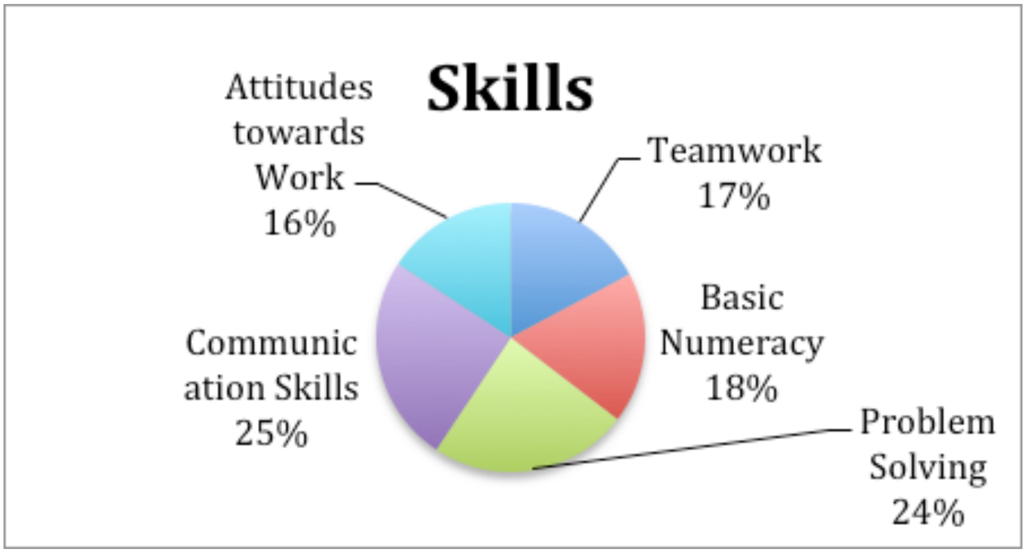


Figure 7: Percent Breakdown of the Skills Employers Seek in Potential Employees

The report mentions that schools must continue the suggestions laid out in *First* Steps report. *First Steps*, published in November 2012, offers businesses' opinions on the UK education system. They included some suggestions for schools and teachers:

- Developing a clear statement of the outcomes all schools should deliver
- Ensuring the accountability system (reform Ofsted, Office for Standards in Education, Children's Services, and Skills, framework to ensure that academic progress and character development are prioritized at schools)
- Empowering school leaders and teachers
- Closing the attainment gap at primary level
- Aligning the curriculum and examination at secondary level with desired outcomes
- Encouraging business engagement

Finally the report summarizes that if schools can continue to follow these suggestions, then their students will be able to enhance these skills to make themselves more employable (CBI, 45).

Transport for London’s Graduate and Apprentice Scheme

Transport for London (TfL) hire graduates from a variety of degree disciplines. Knowing the technical knowledge is important; however, graduates should have the following skills to be hired:

- **Teamwork-** graduates and apprentices should work together as a team.
- **Motivational fit** - graduates and apprentices should demonstrate an understanding of the business challenges TfL faces in the area they’ve applied for, and across the organization as a whole.
- **Customer service skills** - an ability to provide good customer service to both internal and external customers.
- **Management and innovation skills** - graduates and apprentices should be able to respond to, manage, or lead business improvements and change to meet strategic priorities
- **Commercial thinking** - an ability to view situations from a commercial perspective and understand how important cost and efficiency is to our business
- **Planning and organizational abilities** - graduates and apprentices should instinctively take the initiative in situations and be responsible for their own (or others') time, schedule, resources and circumstances to meet objectives
- **Results focus** - delivering business/performance results according to time, budget and quality is essential
- **Good attitude to self-improvement** - recognizing when and how to keep their technical and specialist skills up-to-date so they can be an authoritative source of expertise for their colleagues

Appendix J: Finalized FSAP Student Handbook

Full Speed Ahead!

{The Student Handbook}

The London Transport Museum (LTM) features all modes of transport, old and new

Table of Contents

Session Outline

Research Phase

Every session will begin with some background research. Like all engineers, you must do your research first before designing anything. This phase is your chance to learn about how each activity applies to the real challenges engineers face.

Design Phase

Use the information from the Research Phase to fuel your design process. Make sure your design follows the Mayor's specifications.

Build Phase

After designing a railway component, you will build and test it. Be creative and take risks! Oftentimes you will learn more from watching what does not work than merely picking what does. Note that this section may not be present in every session.

Recap/Discussion Phase

This phase will conclude each activity. This is where you will communicate and justify your ideas to other companies and the Mayor in the form of a presentation, essay, or other medium.

Session 1: Business as Usual

Task: Create a company, logo, motto, code of conduct, and mission statement.

From the early days of the roundel to Edward Johnston's custom typeface, the London Transport Museum (LTM) portrays the development of the London Underground brand

Research

- Brainstorm logos (i.e.: sports, transportation, science, film, food, drink, etc).
- What logos and mottos do you find appealing?

Design

- Create your company. Select a name, choose a motto, and design a logo.
- Collaborate on a company mission statement to convey your company's purpose and goals.
- Deliberate on a code of conduct. How will you handle distribution of labor and disagreements? What other issues might your company face?
- Make sure all of the above elements highlight your company's strengths and help it stand out from its competitors.

Build

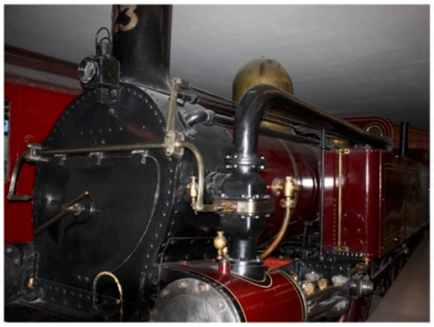
- Play the Transportation Transaction game

Recap/Discussion

- What did you learn about companies and the way they function you did not know before?
- Explain the reasoning behind your company name, motto, logo, mission statement, and code of conduct in a brief presentation.

Session 2: Train of Thought

Task: Design and build a train and track.



This specially modified train (left), now housed at the London Transport Museum (LTM), once ran through the first Tube tunnels. As the model on the right shows, pollution in these early tunnels was a major problem.

Research

- What factors are contributing to greater use of London's public transportation systems?
- What is the basis of the modern design of Tube maps? Who introduced this system, and in what year? What was his or her professional background?
- What factors affect a train's performance?
- How have trains evolved since their inception?
- What types of track exist?

Design

- Weigh the benefits and drawbacks of each available material.
- What will you try to optimize with your train's design?
- How will you ensure a safe and comfortable journey for your passengers?
- How can you make your train more environmentally friendly?

Build

- Your train may have a minimum of 2 compartments.
- Your train must fit in an imaginary box 50 cm long, 15 cm high, and 15 cm wide.
- Your track must be at least 1 meter long.
- Your train must be able to carry the amount of weight or number of passengers requested by the Mayor.

Recap/Discussion

- Perform a cost analysis on your train based on the prices of the materials you used.
- How well does your train perform relative to your expectations?
- How might you improve your train's design? How would you reduce its cost or weight? How would you make it more aerodynamic?

Session 3: Mixed Signals

Task: Research rail signaling and construct a light sensor.

A multi-aspect signal from the Victoria line on display at the London Transport Museum (LTM).

Research

- How do engineers really know where a train is at all times?
- What types of signals do trains use and why?
- How does a circuit work?
- What is current and voltage and how are they related (Hint: research Ohm's Law)?
- What objects do you need in a circuit?
- Research and explain in your own words Kirchhoff's Voltage and Current Laws.
- Research the various symbols used in circuit diagrams.

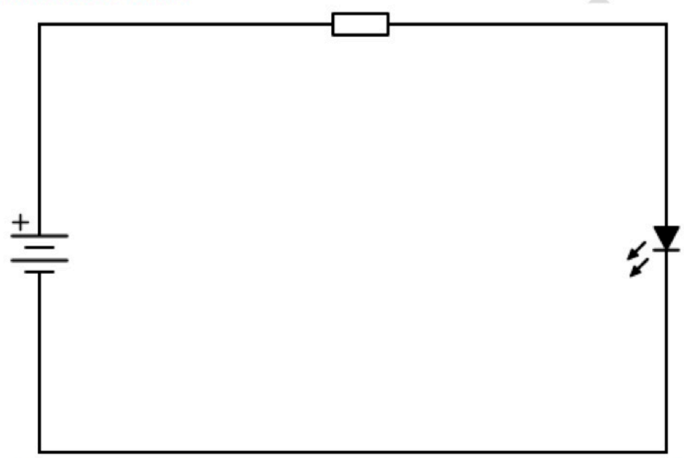
Design

- Design a conceptual signaling system for your train and track.
- Where might you place signals to ensure your train operates safely?
- What is the minimum number of unique signals you need to employ?

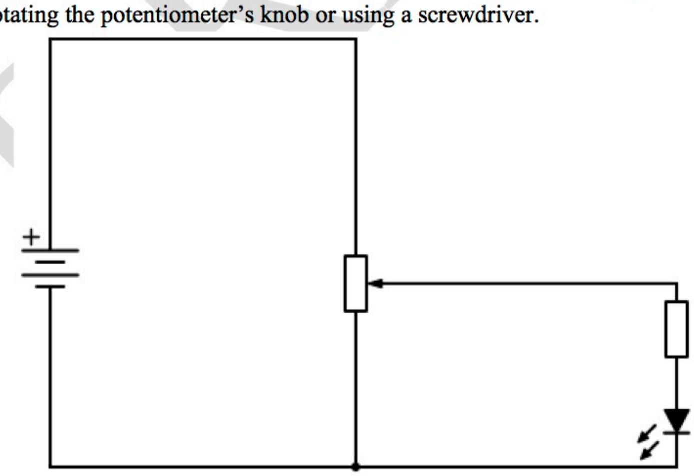
Build

You will need to refer to this session's material in the Resource Handbook in order to build the circuits.

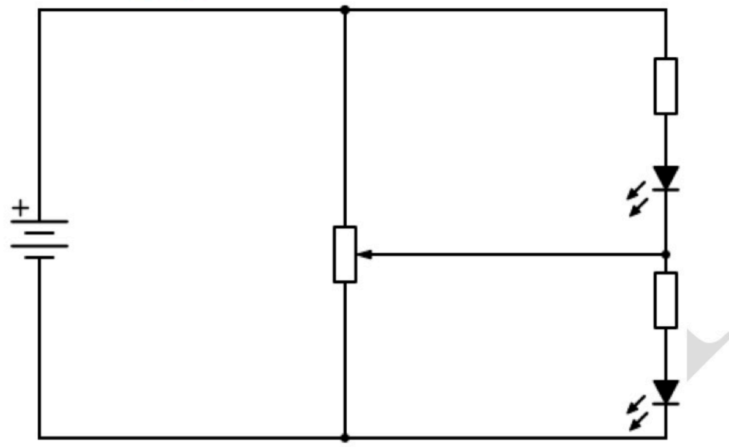
1. Begin by constructing a simple circuit to power a light emitting diode (LED) using the circuit diagram below. Unlike resistors, diodes only let electricity flow in one direction. Make sure you put yours in the right way using the diagram found in the Resource Handbook or you could burn out the component. You can also look there for details on how a breadboard works.



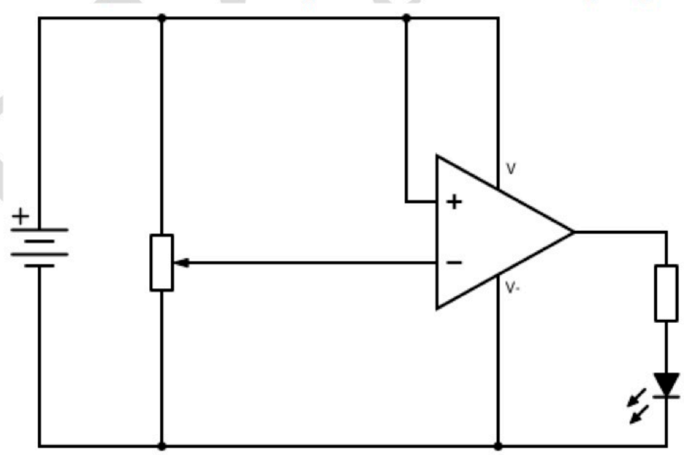
2. Now that you understand how the rows of a breadboard are connected and how to place a diode in a circuit, add the potentiometer to the circuit. This will allow you to dim the led by rotating the potentiometer's knob or using a screwdriver.



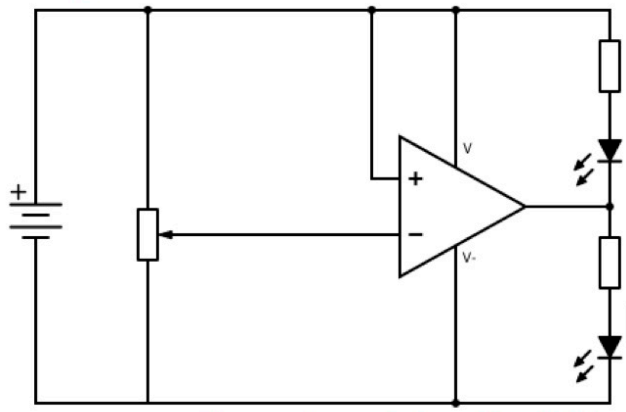
3. The next step is to add another LED to the circuit. You should see the LEDs gradually fade in and out as you rotate the potentiometer. When the potentiometer is completely rotated to either side, only one of the LEDs should be lit.



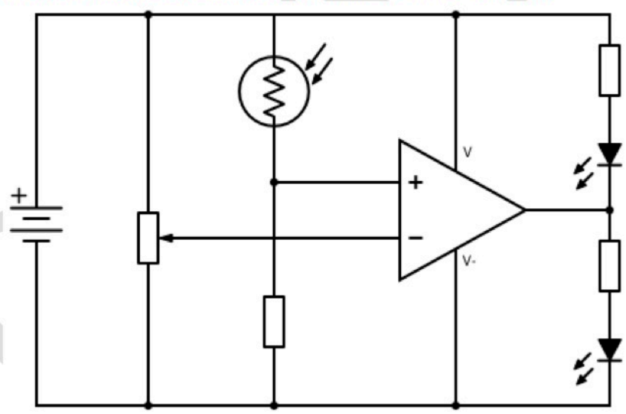
4. Now comes the tricky part, adding the operation amplifier (or the op amp, for short). You will need to look at its datasheet to figure out how to connect each pin, the silvery pieces that insert into the breadboard, of the chip. You will need to connect voltage supply, ground (GND), the + and - inputs, and the output. Your teacher may provide the datasheet or can be found with an internet search of the text on the top of the chip. Notice that the LED only turns off when the potentiometer is rotated completely to one side.



5. Just as you added the other LED in step 3, you will do the same here. Note, only one LED should be on at any one time and they will only change when the potentiometer is rotated all the way to one of its sides.



6. The last two components to add are a resistor and photoresistor. Adding these components will allow your circuit to react to changes in light. You will have to tune your circuit by rotating the potentiometer until the LEDs change.



Recap/Discussion

- What is the importance of electronic circuits in daily life and train engineering?
- How might engineers design failsafe systems for train signaling?
- Where else could you use the circuit you created in this activity on trains?
- Why might the circuit you designed be impractical for real train applications, especially in the Tube?
- Swap the positions of the photoresistor and the 3.3kΩ resistor. How does this affect the circuit?

Session 4: Mind the Gap

Task: Using your gathered research, design and build a bridge.

These pictures at the London Transport Museum (LTM) show how Blackfriars Bridge has changed over time

Research

- What is a truss bridge? Why was this type of bridge so common? Look into three different types of truss designs (Pratt, Warren, Howe, or others). Weigh the pros and cons of each.
- What is a more modern type of bridge design (Suspension, girder, segmental, etc)? Why have these designs become so popular in recent years?
- Why were arches so common in early bridges? Are they still used today?
- What materials are used in bridge design? How do engineers reinforce concrete?

Design

- How will you make your bridge as strong as possible? Remember, in many bridges, including trusses, the main support lies below the deck.
- How can you add a support in the middle of the span?
- What type of bridge will you make? What are the benefits of the style you chose?
- How can you make your bridge aesthetically pleasing? Remember, bridges are highly visible.
- How can you make your bridge more environmentally friendly? Study the solar panels on Blackfriars Bridge for inspiration.

Build

- Your bridge must be at least 30 cm long.
- Your structure should be able to support as much weight as possible.
- You may use any materials the Mayor approves. However, lighter, cheaper bridges will receive more points.

Recap/Discussion

- What happened to the Tacoma Narrows bridge? How has the incident impacted bridge design?
- How did the Millennium bridge in London earn its nickname the "Wobbly bridge"?
- What is the longest bridge in the world? What are some of the challenges the engineers responsible for the project faced?
- Maintain your company's professional image. Write a letter to the community near the construction site of your bridge that apologizes for any inconvenience caused by the construction, thanks them for their patience, and explains why this project is important and how it benefits them.

Session 5: Tunnel Vision

Task: Using your gathered research, design and build a tunnel.

These models at the London Transport Museum (LTM) show two ways to tunnel by hand, the cut-and-cover method (top) and with a Greathead Shield (bottom).

Research

- Why have arches and tubes consistently been used for tunnels for thousands of years?
- What is the main problem with using coal locomotives in tunnels? How did Victorian engineers attempt to solve this problem?
- Some cities have elevated rail lines instead of underground networks. What are the pros and cons of this system? Is this solution feasible for modern London?
- What is the cut-and-cover method of tunneling? Is this technique feasible today?
- What is tunnel shielding? Who was the engineer responsible for the first successful deployment of this technique, and on what project was it used?
- What materials are used in the construction of tunnels?
- How have engineers been able make bridges and tunnels longer and deeper than ever before?

Design

- How many lanes will your tunnel have?
- How can you maintain the air quality of your tunnel?
- How will you make your tunnel as large and strong as possible?
- What materials are most useful for this application?

Build

- Your tunnel must be at least 30 cm long.
- Your structure should be able to support as much weight as possible. Points will also be awarded for the cheapest and largest tunnel.

Recap/Discussion

- What costs were associated with your structure?
- Could your structure have any unexpected impacts on the area around it?
- What sort of maintenance might be associated with your tunnel?

Session 6: Station Fixation

Task: Design and build a tube station.

Model train stations on display at the LTM

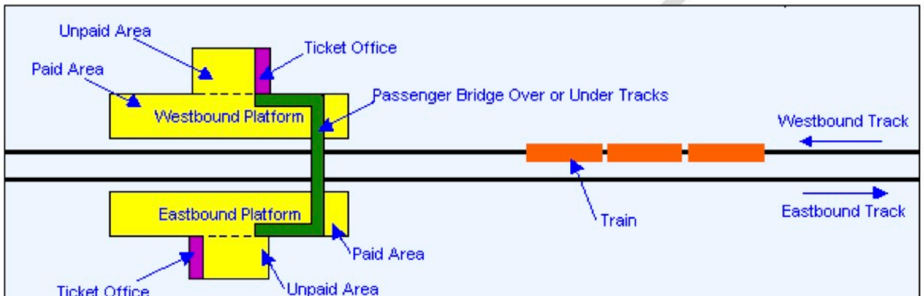
Research

- Brainstorm underground tube stations that you have visited in London. Are there any tube stations that stand out? Why? If not, how would you make them stand out?
- What materials are used in building a station? Think about what materials you would use.
- What area of London will your tube line service? Make sure it goes through all the zones of the tube (zones 1 through 6). Will it cross other tube lines? For each zone, decide where your stations will go. Refer to the Resource Packet for the tube map.
- Decide where your signature station will go. Why did you choose that location? Be prepared to justify this choice.

Design

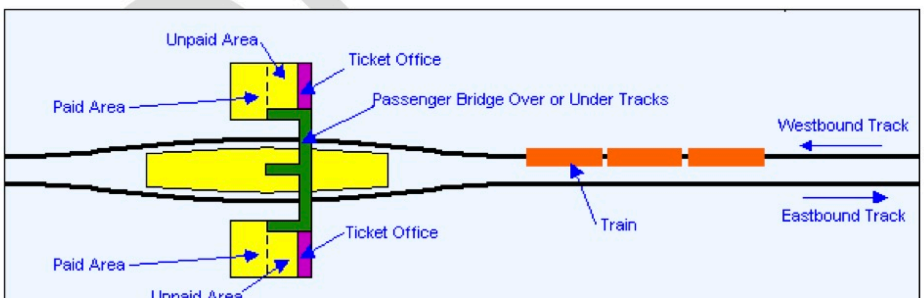
There are multiple designs for station platforms, including: side platform, island platform, elevated platforms, and an elevated with ticket halls below platforms.

- **Side platforms** are the most basic design for a double track railway line. It has two platforms (one for each direction of travel). Each platform has a ticket office and other passenger facilities (i.e.: bathrooms, refreshments, etc.). The two platforms are connected by a footbridge.



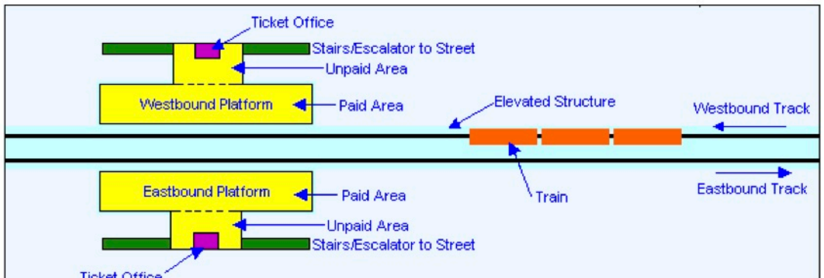
Typical Side Platform Station Layout

- **Island Platform Station** is the cheaper form of station construction. It is a single platform serving two tracks passing on either side. Island platforms are generally wider than single platforms. A bridge or underpass is usually provided.



Typical Island Platform Layout

- **Elevated Station with Side Platforms are popular in cities.** They are cheaper than underground railways and are better at flowing passengers out of the station. *Note: the track is elevated.*



Typical Elevated Side Platform Station Layout

- The **Elevated Station with Ticket Hall Below Platforms** have the ticket office and gate lines above or below the platform level. Because many of the stations are built at road intersections, this station design may have a required height structure to be built in order to allow road traffic (cars, buses, trucks, etc.) to pass beneath.

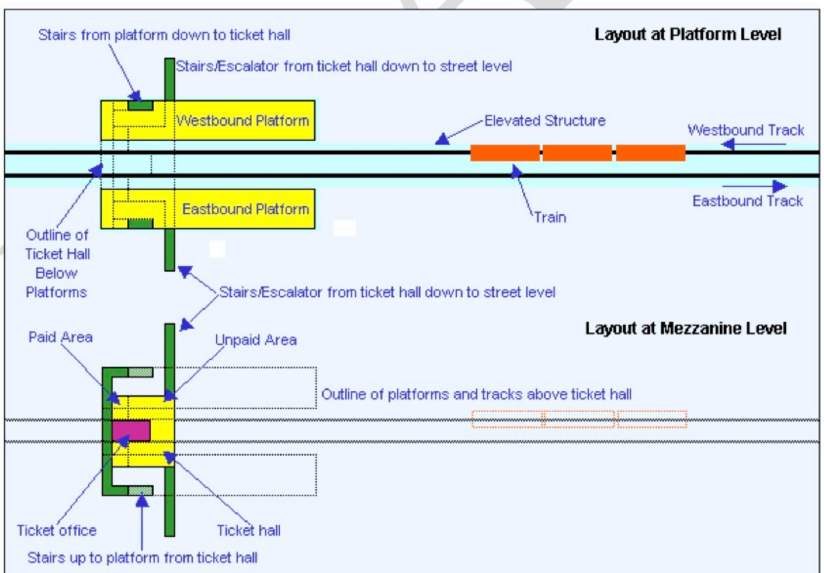


Diagram of Elevated Station with Ticket Hall Below Platforms

Keeping the above platform designs in mind as well as your own experience travelling on the tube, design your platform. Remember, train stations get very hectic during rush hour. How would you guide your crowds around the platform? Create a floor plan of your platform and entrances/exits.

- How will:
  - Passengers reach the trains from street level? And how will you make your station accessible to people with disabilities?
  - Electrical devices in your station be powered? How will you reduce the environmental impact of your station?
  - Customers receive travel updates?
  - Passengers be able to buy tickets or Oyster cards?
- How much will your design cost? When all the elements are put together, perform a cost analysis.

Build

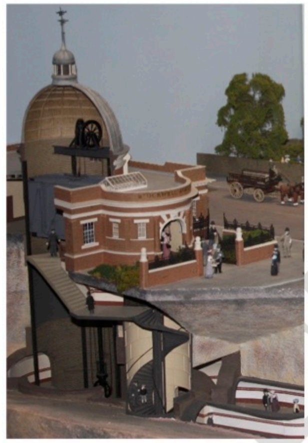
- Your platform must accommodate all cars of your train.
- Include placeholders for escalators, stairs, ramps, and/or elevators.
- Ensure passengers can move about your station quickly.
- Mind the gap! Make sure your train gets as close to the platform as possible.

Recap/Discussion

- Can you design signs and directions for passengers at your station? What would your signs say? Where would you place signs to make them the most effective?

Session 7: Time is of the Essence

Task: Use the Critical Path Method (CPM) to schedule a complex project.



This model at the London Transport Museum (LTM) shows the many complex features of an early Tube station. As modern stations feature ever more amenities, efficiently constructing them has become a complicated challenge.

Research

- Explore your previous knowledge of schedules and your intuitions on how they may be designed.

Design

- As a class, explore the design of the Critical Path Method using the **Theater Production** example.

Build

- Create a schedule for the station design using the provided table.
- What is the shortest length of time required to complete all activities in the station design? Which tasks are on the critical path?
- Answer the remaining questions included with the station design activities, keeping in mind how you arrived at your answers.

Recap/Discussion

- What patterns did you notice in the float time for different activities?
- What happens to the float time on activities like "Rehearsals" and "Actor Runthrough" if choosing a cast takes one day longer than expected?
- This method is often used with much larger projects containing hundreds of activities. What challenges would you expect with something of this size?
- Accidents and delays happen. Which paths are near critical paths, and what are some likely delays for the theater or station schedules that could cause a new critical path to appear?

Session 8: Rail Lines and Line Graphs

Task: Analyze rail graphs.

This model of London at the London Transport Museum (LTM) shows the connection between the city's buildings and the Underground's Tube lines (the front and back of the model are the top and bottom images, respectively.

Research

Work through the next few physics problems using basic kinematic relations. Try to find the necessary formulas online or in your textbooks (Hint: look for the major kinematic equations, Newton's Second Law, and energy and momentum equations), but if you are stuck ask the Mayor for help. How might engineers use the information derived from this mathematical analysis? How might you use it in your own railway design?

1. Your train has a mass of 250,000 kg and is traveling with a kinetic energy of 15.125 MJ. What is the train's velocity? **Ans: V = 11 m/s**

2. Assume your train's air brakes can exert a force of -200,000 N on the train. What rate of deceleration does this cause? Include a free body diagram of this scenario.
Ans: a = -.8 m/s/s

3. Signals tell conductors the condition of the section of rail ahead. Put very simply: green means "Go"; double yellow means "The next signal is yellow"; yellow means "Slow down. The next signal is red"; and red means "Stop". Obviously, a station would display a red signal to allow passengers to enter and exit the train. How close to the station's red signal can an engineer place a yellow signal so your train can safely stop? How long does this deceleration take? **Ans: t = 13.75 s; X = 75.625 m**

4. (Optional Problem) Now assume the electric motor on your train can exert a force of 125,000 N on the train. Draw a free body diagram and find the rate at which your train can accelerate. If your train is 100 m long, how much time does it take for it to fully leave the platform? Assume the platform is the same length as the train. What is the momentum of your train at this instant (Hint: You will need to find the velocity of your train in order to calculate its momentum)?
Ans: a = .5 m/s/s; t = 20 s; V = 10 m/s; p = 2.5*10^6 kg*m/s

Design
Analyze the simple graphs shown below. For each scenario find:

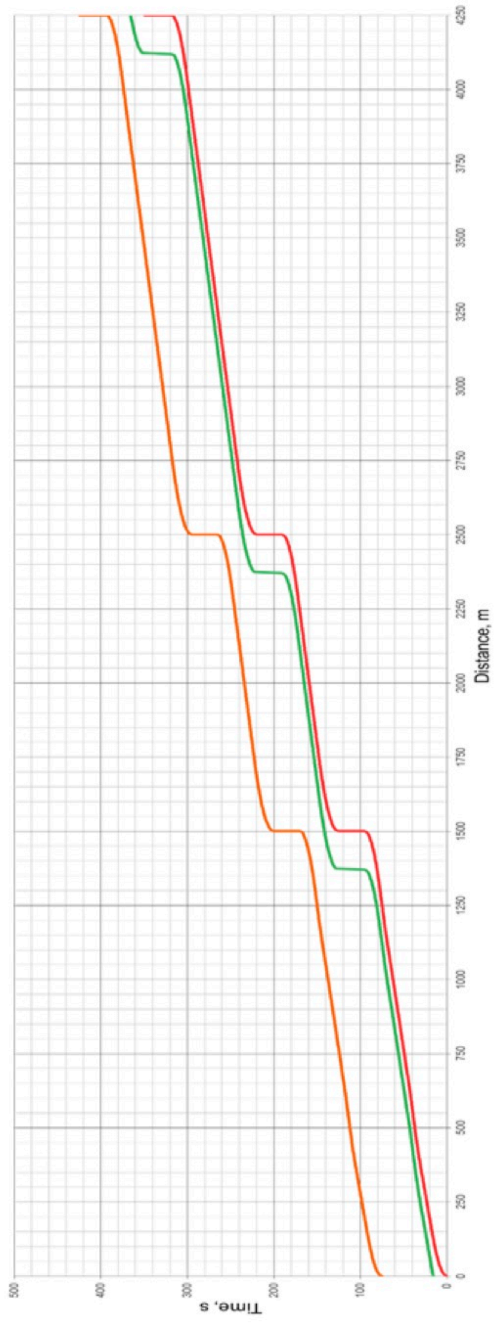
- The number of stations on this section of line.
- The rail line's headway. Headway is defined as the time between when identical points on two trains pass through the same point on a rail line. A simpler definition is: the time interval between two vehicles (automobiles, ships, or railroad or subway cars) traveling in the same direction on the same route.
- The length of the train being analyzed.
- Whether or not a collision will occur; if so, how can you fix the problem? If there are no collisions, how can you increase the efficiency of the line?
- The trains delay a certain distance before accelerating when they enter a zone with a higher speed limit; why do you think that is?

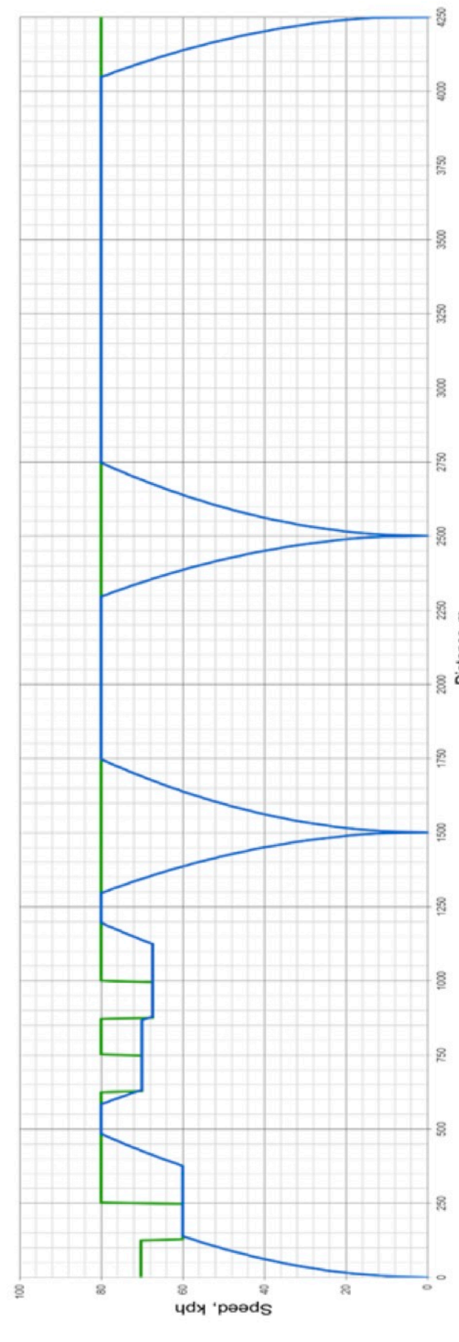
Identify differences between the speed versus time graphs of successful cases and problematic ones. Compare the train length and headway from each of the three graphs; can either of these values be changed to optimize the line or prevent collisions?

KEY:

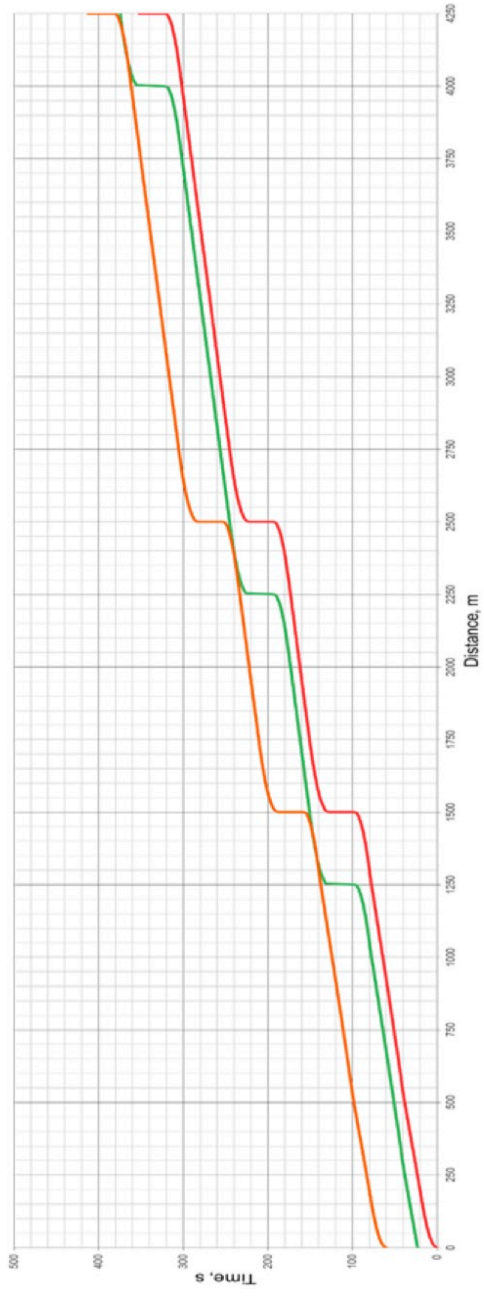
- Top Graph
  - Front of Train 1
  - Back of Train 1
  - Front of Train 2
- Bottom Graph
  - Train's speed
  - Speed limit

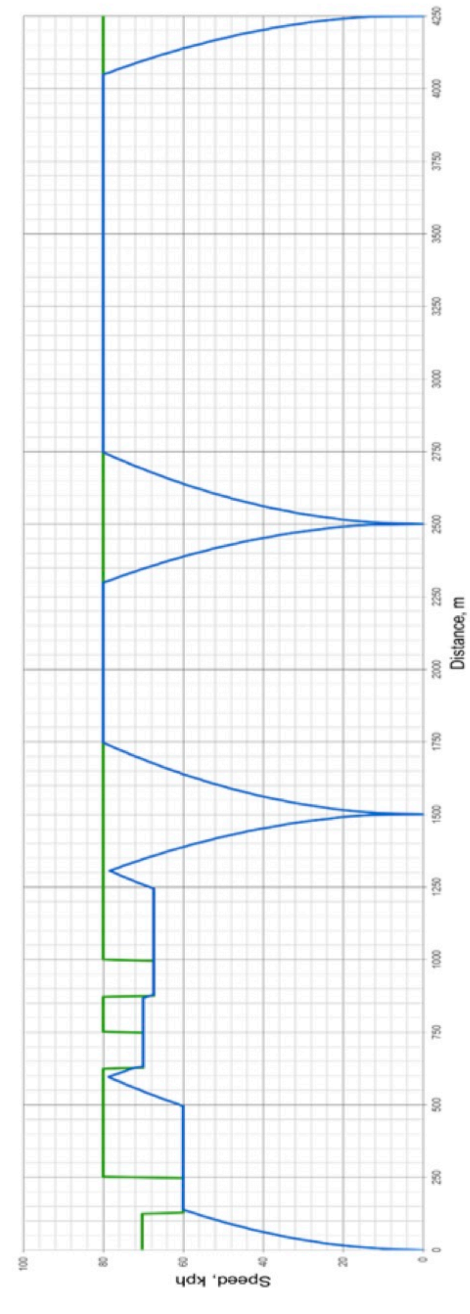
Case 1:



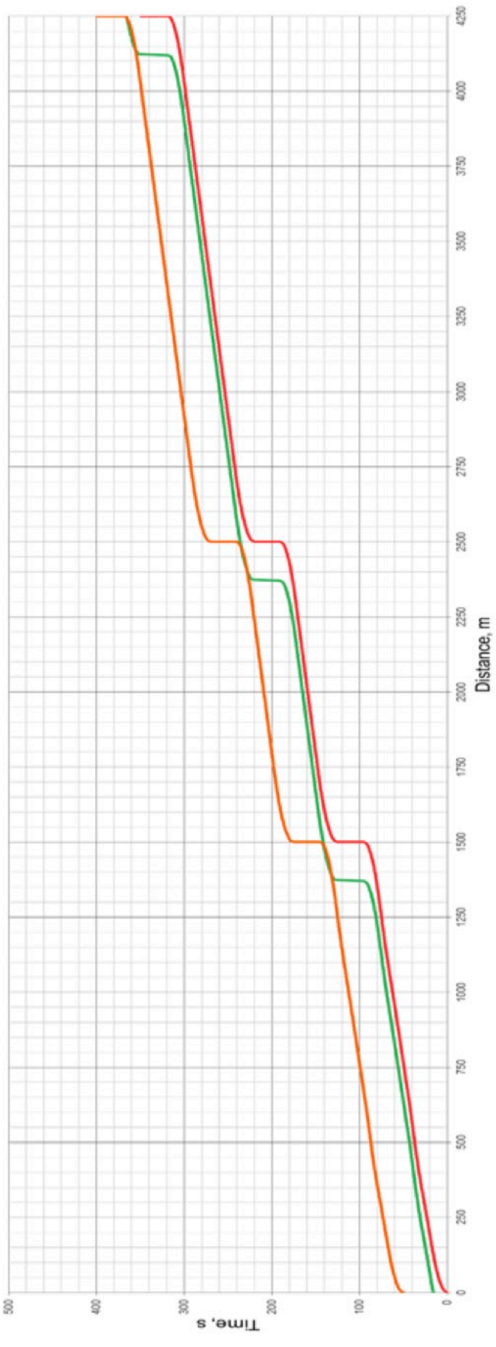


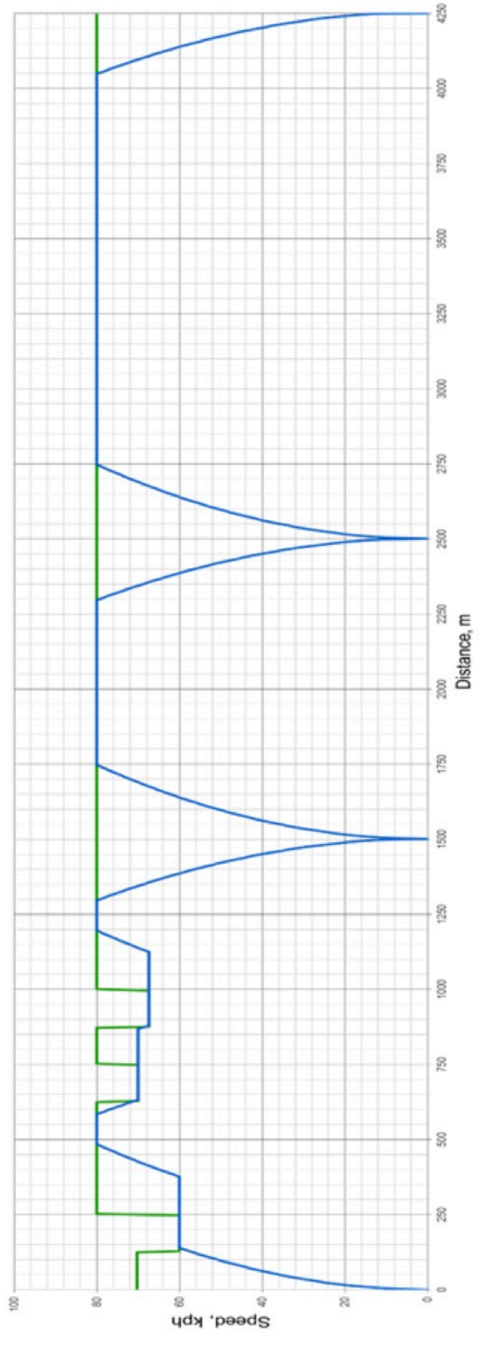
Case 2:





Case 3:





Recap/Discussion

Communicating complex ideas to people without a science background is one of the many challenges engineers face each day. Write a clear, concise report of the calculations you completed, but keep your audience in mind. Remember, the Mayor probably will not want too much detail on how you generated your solutions (although other engineers certainly will), but will only be concerned with your final results. Include an explanation of the features shown on the train graphs (~250-500 words).

Session 9: Show Time

Task: Present your proposal to the Mayor and competitors.

The Skills Room at the London Transport Museum (LTM) is used for professional presentations

You have worked hard to create what you did, be it a tunnel or a full rail line. You have learned a lot, considered many different ideas, and tested and improved your design. Now is the time to show what you have achieved!

Present your model to the Mayor and your competitors. This is your chance to explain everything you have learned, and by extension why your design is the best. You can focus on many different and important aspects of your design (i.e. - strength, safety, longevity, cost, appearance, etc.) in your presentation as long as you remember to make your business stand out.

Ultimately the Mayor will decide how they want proposals, but consider: a persuasive written justification; a slide-based presentation, a demonstration, submitting a technical report of theorized performance and actual testing data, and/or a cost analysis. The ability to explain your ideas to people, especially those without a background in science, is an absolutely crucial part of the team-based world of engineering!

Session 10: A Journey Back in Time

Task: Trip to the London Transport Museum.

A view from the mezzanine at the London Transport Museum (LTM)

Suggested exhibits to visit that correlate to the sessions studied in the program are listed in the table below. Feel free to explore the museum!

<table>
<tr><th>Time Period</th><th>Exhibit</th></tr>
<tr><td>1800s</td><td>First railway
Carriage wheels versus railway wheels
River transport/bridges
Important People: , Elizabeth Birch (Westminster Omnibus Association)</td></tr>
<tr><td>1900s</td><td>Business as Usual
Posters
Edward Johnston’s roundel and font
Important People: Frank Pick, Albert Stanley (or Lord Ashfield), Robert Hope Selbie, Harry Beck
Train of Thought
Interactive monitors/tablets
Steam vs. electric propulsion
Steam/Smoke ventilation display
First through Third class coaches
Tunnel Vision
Brinell reinforcements
Greathead Shield model
Steam vent diorama
Cut-and-Cover diorama
Station Fixation
Architecture plans
Escalators/Lift design
Waterloo Station
Important People: Charles Holden</td></tr>
<tr><td>Present-day London</td><td>Train driving simulator
Crossrail*
Future Designs*</td></tr>
</table>

(* Please note that these exhibits are temporary and may change in the future)

Jot down some ideas below as you explore the museum:

Appendix K: IEMP BTEC Information

BTEC Reference Sheet

The Basics

- Applied learning qualification from pre-GCSE (BTEC Entry Level) to Degree Equivalent (BTEC Higher Nationals)
- Students take responsibility of their own learning and develop practical, interpersonal, thinking skills
- Are sector specific (engineering, business,
- Levels in ascending order: Award (A), Certificate (C), Diploma (D)
- Grading: Pass (P), Merit (M), Distinction (D), High Distinction (D*)

The Breakdown

1. **Entry (Level 1)**
   - Learners gain confidence and basic skills
2. **Firsts (Level 2)**
   - An introduction to a particular sector. GCSE equivalent.
3. **Nationals (Level 3):**
   - Specialist qualifications for students. A-Level equivalent.
4. **Specialist & Professional Development qualifications (Level 4-8):**
   - Short courses about professional development
5. **Higher Nationals (Level 5):**
   - Higher education qualifications. Recognized by universities & professional bodies.

After BTECS, Students can:

- Pursuit of a particular job or work in a particular industry
- Opportunity to study a new qualification
- Opportunity to undertake an Apprenticeship

BTEC subjects offered (relevant to Engineering):

- Applied Science
- Business
- Construction and the Built Environment
- Engineering (Aeronautical, Electrical, Mechanical, etc.)
- Information Technology (IT)
- Land-based Technology
- Vehicle Technology

Appendix L: OCR GCSE Subject Mapping

Maths
LO1: Learn how to plan the making of a prototype
LO2: Understand safe working practices used when making a prototype
LO3: Be able to produce a prototype
LO4: Be able to evaluate the success of a prototype

Additional Science
LO1: Know how commercial production methods, quality and legislation impact on the design of products and components
LO2: Be able to research existing products
LO3: Be able to analyse an existing product through disassembly
LO5: Be able to generate design proposals using a range of techniques
LO6: Know how to develop designs using engineering drawing techniques and annotation
LO7: Be able to use Computer Aided Design (CAD) software and techniques to produce and communicate design proposals

Science:
Themes: Materials, Time/resources management, Precision, Accuracy, Quality, Supply Chain, Production Costs, Market research, Improvements in materials, Budgets, Dimensions, Drawing, Scale, CAD Drawing, Sustainability, Sustainable design and environmental, New technology and materials, Life Cycle Analysis, Energy and Power sources, Safe disposal toxic materials, and Chemical economics.

Learning Objectives (LO):
LO1: Know how to plan the making of a prototype
LO2: Understand safe working practices used when making a prototype
LO3: Know about wider influences of design of the new products

Sub LO:
- Design briefs specifications and user requirements
    - Design cycle
    - Identification of design
    - Relationship between a design brief and a design specification
    - Product analysis and research
    - Commercial production methods that impact on product/component design
    - Impact of manufacturing processes on product design
    - Considerations for product end of life
    - Importance of conformity to legislation, quality and safety standards
- Developing and presenting engineering designs
    - Hand-drawing techniques to design and present ideas and concepts
    - Annotation and labelling techniques that demonstrate design ideas
    - Use of ICT software to produce, modify, and enrich design proposals

- 3D design realisation
    - key considerations when making a prototype, ie
        - interpretation of a product specification
        - processes for making a prototype model – use of planning tools (eg Gantt chart, flow chart, tables)
        - resources when making a prototype (eg materials, component parts, cutting lists, tools/ equipment, health and safety requirements/ hazards, time requirements)
        - planning stages used in the making a prototype (eg processes testing, evaluation)

Subjects discussed: (C= Chemistry, P = Physics, B = Biology)

- Making Polymers (C)
- Designing Polymers (C)
- Paints and Pigments (C)
- Construction Materials (C)
- Metals and Alloys (C)
- Making cars (C)
- Making crude oil useful (C)
- Using carbon fuels (C)
- Clean air (C)
- Collecting energy from the Sun (P)
- Generating electricity (P)
- Global Warming (P)
- Fuels for power (P)
- Nuclear radiations (P)
- Stable Earth (P)
- Population and pollution (B)
- Sustainability (B)
- Uses of radioisotopes (P)

Mixed Signals: Electronics H605- Signal Processing
Station Fixation, Train, Track, Bridge, Tunnel- if use Solid Works- maps to Additional Science & Science
Train Graphs & Rail Lines- Math

Appendix M: FSAP LTM Program Coordinator Handbook and Letter

To whom it may concern,

The Full Speed Ahead Program (FSAP) is designed to inspire year 10 and 11 students to pursue a career in engineering through hands-on activities and connections to the London Transport Museum's (LTM) rich collection. There are ten sessions, including a visit to the museum galleries. Teachers may choose to use any number of the sessions, which combined will have students create a train and a track with a bridge, tunnel, and station, among other tasks. We believe this curriculum will inspire students to pursue engineering, and empower them with the confidence to do so, as well as show them the breadth and depth of engineering as a field.

Our development of the program included input from educators, engineers, and students in a small-scale pilot of the most challenging sessions, as well as members of the LTM's Learning Office. We recommend that you meet with teachers who use the program to gather feedback on what went well and what should be improved; for example, you may hold a focus group, visit participating classrooms, or collect information via phone or email. These comments, paired with the recommendations included in our final report, could be used to improve the FSAP over time.

We have suggested handling objects for each session that can help enhance a student's experience in the FSAP. Engineering Ambassadors from Transport for London could bring one or two of these objects to classes using the program to further engage them in real-world engineering challenges. These suggested items should be set up in a box, which has an inventory sheet, the objects to be used, and a laminated sheet for each object with a picture and some notes for Engineering Ambassadors to invite a discussion with students on the features of the object. A list of the suggested handling objects and relevant exhibits at the LTM is included here:

Session	**Handling Object/Link to LTM**	**Sign in**	**Sign out**
Business As Usual	Frank Pick Metroland Exhibit Metroland Door Handle Johnston Woodblocks (T&E)	N/A	N/A
Train of Thought	Composite Conductor Rail Fact Sheet (T-06) Pandrol Clip Fact Sheet (T-02) (T-16) Pressure Switch Fact Sheet (T-11) (T-12) Rail Fastenings Fact Sheet (T-01) (T-13) (T-14)		
Mixed Signals	Capacitors (E-07) (E-08) T-Piece Fact Sheet (T-05) Hawkbox Tuning Unit Component Fact Sheet (S-17) Indication Contact Arrangement Fact Sheet (S-13) (S-14) Indicator Push Rods Fact Sheet (S-0.5.1) (S-0.5.2)		
Rail Lines and Line Graphs	Relay Fact Sheet (S-15) (S-16) Wiring Cables Fact Sheet (S-01) (S-02.1-2.9) (S-18.1) (S-18.2) Unicoder Communication System for London Bus Services		
Mind the Gap	Post Tensioning Cable Fact Sheet (C02)		
Tunnel Vision	Concrete Fact Sheet (C-01) Link to Tunneling Exhibit at LTM		
Station Fixation	Water Meter (C-07)		
Time is of the Essence	Microprocessors / Heatsinks (E-01) (E-06) Random Access Memory (RAM)		
Show Time	N/A	N/A	N/A
Journey through Time	Refer to Session 10 of the Teacher Handbook	N/A	N/A

LTM Handling Objects and Exhibits that match with the FSAP Sessions

The handling objects are used in the collection to help students not only understand the evolution of transportation technology but also understand how engineering solutions are changed over time. Please refer to the LTM's accompanying handouts for detailed descriptions about each of these objects.

Your role in keeping these objects available for use in the FSAP and gathering feedback for its improvement is appreciated.

Sincerely,

Lauren Baker

Casey Broslawski

Cameron Crook

Shannon Healey

The FSAP's developers from Worcester Polytechnic Institute

Appendix N: Inspire Engineering Mentoring Programme Sample Session

Session 10: Engineering Design

Objectives

You may have noticed that Royal Greenwich University Technical College has a fully functioning train carriage in their possession. In this section of the program, you will help participants:

- Experience different facets of an engineering problem.
- Work through problems and solutions.
- Have students think critically about train design.
- Facilitate teamwork.

Session Agenda

Activity	Description
Engineering Activity (60 minutes)	Visit the train Design a train

Facilitation

The goal is to inspire and excite students, and have them think critically about the train's design. Help students identify and describe several parts of the train through:

- Reverse engineering sections
- Analyzing a part's form and how it relates to its' function
- Provide hints and ideas for students, but avoid giving them an answer
- Join the mentees' brainstorming for parts you are unfamiliar with

At a certain point the students may ask how your work relates to railway engineering. Be sure to:

- Answer freely
- If you do not work specifically on trains you can discuss how some of the design processes and considerations present in the carriage are related to your own work (i.e.- factor of safety, manufacturing, materials selection, complex circuits, etc.)

Improvement

Help students identify aspects of the train that either have been refined through the years or could be improved. Advise your mentees as they design or build a futuristic train carriage that capitalizes on these improvements. There is no wrong answer; let the students be as creative as possible.

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