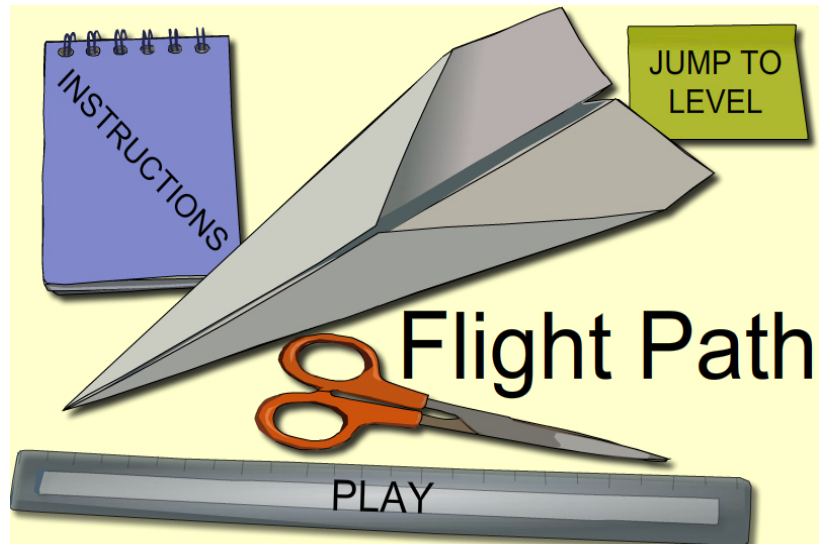


Development of Key Stages 2 and 3 Teacher Resources in the Areas of Space and Flight for the Science Museum in London



By
Jake Cabrera
Alyson Talbot
Jon Tashman
Jonathan Zoll



The views and opinions expressed are those of the authors and do not necessarily reflect the positions or opinions of Science Museum in London or Worcester Polytechnic Institute.

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AN INTERACTIVE QUALIFYING PROJECT SUBMITTED TO THE FACULTY OF WORCESTER POLYTECHNIC INSTITUTE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE BY

Jake Cabrera

Alyson Talbot

Jon Tashman

Jon Zoll

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Report Submitted to:

Peter Hansen

Stanley Selkow

Nicola Upton-Swift

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Abstract

The Science Museum in London's overall goal is to engage students in science. This project developed prototypes of teacher resources for use in the classroom or museum on the topics of Space and Flight. The design was based on teacher interviews and the museum's research about teachers' wants for resources and what engages students. From the analysis of this data, we developed resource prototypes for use in the classroom or museum and created an online flight interactive game.

Acknowledgements

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Executive Summary

The United Kingdom is currently experiencing a decline in the number of students who pursue science in further education or a professional career in the scientific field. The UK Parliament Select Committee on Science and Technology has noted this as an important problem, and made several recommendations to address the issue. One of these recommendations states that the only way to secure large numbers of future students in science education is by exciting them about science at an early age (United Kingdom Parliament, 2008). A way to stimulate children outside the classroom in the realm of science is by a visit to a science museum.

The Science Museum in London is one of the most popular places for school groups to visit in order to learn about science through an informal educational experience. Students are able to touch or see certain things on display which complements their reading and learning about science in class. One of the goals of the Science Museum is that by 2012, every child in the United Kingdom will have a Science Museum experience. The experience could be visiting the Science Museum, playing one of Science Museum's online games, using a Science Museum educational resource, or even learning something from a teacher who attended a Science Museum course. To get students engaged in science while in the museum or within the classroom, the Science Museum has developed a number of teacher resources. Unfortunately, there were not teacher resources developed for all topics covered within the museum or in the UK science curriculum.

The goal of our project was to develop teacher resources related to Space or Flight Galleries that would engage the students in Key Stages 2 and 3 (age 7-14) during their visit to the Science Museum or while in the classroom. To achieve this goal, we interviewed teachers and the Science Museum Staff to understand their opinion of current teacher resources. We then used this information to design prototype teacher resources related to Space and Flight and an online game, Flight Path. We tested these resources with teachers and students and provided recommendations for the further development of

those suggestions. Finally, we developed recommendations for the development of our resource prototypes and Flight Path.

Teacher Resources

The main methods of research were interviews with teachers and staff along with studying past research of the Science Museum. The analysis of the data from the teacher interviews showed that teachers consistently wanted resources that were easy to use, relevant to the curriculum, and compatible with interactive whiteboards. Through these interviews, we also investigated students' engagement with educational resources, the Science Museum, and more specifically the galleries and the curriculum related to Space and Flight. Teachers stated that their students enjoyed and absorbed the most information from hands-on activities. Unfortunately, due to time limits during a museum visit, many teachers reported that most student groups never actually visited the Space or Flight Galleries. Similarly, in the classroom many teachers did not have the time to use resources that required much preparation or construction. Previous research in this area also showed that teachers wanted a resource that allowed controlled discussion with their students in the museum or their classroom. Also, the museum's website was often visited by teachers, and they usually enjoyed the website and found it to be an effective resource.

Based on our findings through these interviews and research, we developed four criteria to guide the development of our teacher resources. Any resource must:

- relate to the curriculum
- be easy to use for students and teachers
- be quick to prepare for teachers
- engage students.

In addition, our interviews and research indicated that students learn best through hands-on and interactive activities that enable the students to create or investigate the topic on the and in a creative manner. The principles guided the development of our prototype resources.

Design of Teacher Resources for Space and Flight

We developed resource prototypes for Space and Flight and separated them for use in the classroom or the museum. The classroom resources were hands-on activities.

The museum resources were dynamic worksheets that provoke discussion and thought from the students. We also developed a resource called Spinners that can be implemented in either the classroom or the Flight Gallery. Lastly, we developed an online interactive flight game called Flight Path to be placed on the Science Museum's website that can be used by any student with internet access or in the classroom on an interactive whiteboard. To provide simplicity, teacher notes were created for each resource. The main goals of these notes were to provide teachers with the importance of the experiments, what students should learn from them, the proper procedure, and how to motivate students to think about the concepts the experiments covered. The classroom resources were the Balloon Rocket, Light Upon Earth's Rotation, and the Circus Activity. The Balloon Rocket, made of a dental floss course, a straw, and balloon, was used in the classroom for the topics of Space Exploration and Newton's Third Law, which states for every action there is an opposite and equal reaction. The Light Upon Earth's Rotation described the importance of the Earth's Rotation and how it relates to the length of a day and year. The Circus Activity demonstrated three simple concepts through three separate activities about air flow, air pressure, and lift that, when used together, teach students about the importance of the shape of an airplane wing. All the three simple experiments were constructed of simple materials, such as balloons, string, paper, straws, plastic bottle, and a coat hanger.

The museum resources were created to engage students within the Space and Flight Galleries. The Space and Flight Galleries are object-rich galleries with little interactivity to entertain students. Therefore the Scavenger Hunt and Advertising Campaign worksheets were easy for the teachers to print out and allowed students to interact with the artifacts present in the galleries. The Scavenger Hunt incorporated a concept learned from our research into teacher resources at the Tate Modern museum in which, students are asked to finish a half-completed drawing of an object within each Gallery. The Advertising Campaign has students endorse their favorite artifact in the respective Gallery with the goal to convince others to visit that specific exhibit.

The Spinner activity can be used either in the museum or the classroom. It was recommended for use in the Flight Gallery because of the observation bridge present in gallery from which students could drop the Spinner from. For simplicity, the Spinner

activity was constructed out of a paper template that we created, and was simply folded and torn to create a paper version of a helicopter. The Spinner was used to explain the concept of air resistance to students, and had a detailed set of teacher notes.

We tested the prototypes with teachers and students and used their suggestions and improvements in achieving our final designs. Self-testing was done on all resource prototypes. The testing provided us with extensions, discussion ideas, and changes to the procedure for clarity of each of the proposed resources. In the instances of an activity with multiple procedures, we eliminated the more difficult procedures through self-testing.

The student testing occurred with Year 7 students in a science club at the Bridge Academy, London. Only the Balloon Rocket was tested due to the time constraints of the session. The students were immediately engaged in the activity due to introducing competition into the resource in the form of a race among five different groups' Balloon Rockets. As displayed



Figure 1: Students creating the Balloon Rocket

in Figure 1, the students also demonstrated that they could construct the Balloon Rocket with no difficulty. At the end of the session, students proposed several suggestions, which were added to the extension section of our teacher notes.

We also tested all of our prototypes with both teachers and museum staff. This testing session provided us with feedback on all the proposed resources as well as, ideas for recommendations to the Science Museum. The most significant suggestion we received during the testing was a new concept for the Paper Wing. The team took the proposal and developed a new resource to teach students about lift, the Paper Flyer. The Paper Flyer was a resource created out of paper, string, and straw that demonstrates lift and how the shape of a wing causes lift.

The resources we developed were in the prototypes stage of development therefore we recommend further developing for each prototype. The first

recommendation for our developed prototypes is to further test all prototypes. The next recommendation is to provide picture procedures for all prototypes based off of our template for the Spinners. We also recommend that the Science Museum creates three different level Scavenger Hunts to challenge all students based on their ability. Lastly, we recommend to further develop the Light Upon Earth's Rotation Activity.

Flight Path

The online interactive flight activity, Flight Path, was developed to give teachers a method of teaching the fundamentals of flight in class or as homework. Flight Path was built in Adobe Flash[®] according to the guidelines provided by the Science Museum web development team. The purpose of the game is to introduce concepts that are covered in the classroom and connect them with the historical focus of the Flight Gallery in the museum. It simulates the flight path of a paper airplane by taking into account the forces of drag, lift, and gravity. It also featured various pop-ups that helped explain the concepts behind flight as well as information on the history of flight as suggested by the museum staff. The pop-ups provided information on some of the facts of the game. For example, when the positions of the elevators of the plane's wings were changed it caused the plane's flight path to loop. There were ten levels created for the game and each displays a historic event in aviation. The levels also became progressively harder throughout the game either by putting obstacles in the students' way or by changing the position of the target. An example of the game is shown in Figure 2. The goal of the game for the players was to hit the target at the other end of the screen by using the simulated forces present in the game.

The game underwent self-testing to test and find bugs within the game. Also, teacher and staff testing provided us with information to fade the background from the foreground to prevent confusion between the distinctions of the two. This was done to not only to help students, but mostly to ensure students with visual disabilities could play the game as well. After the testing session we also provided clearer instructions and links to the curriculum for teachers. We recommend that the game be further tested with teachers and students because of time constraints this was not able to be completed during our time scale.

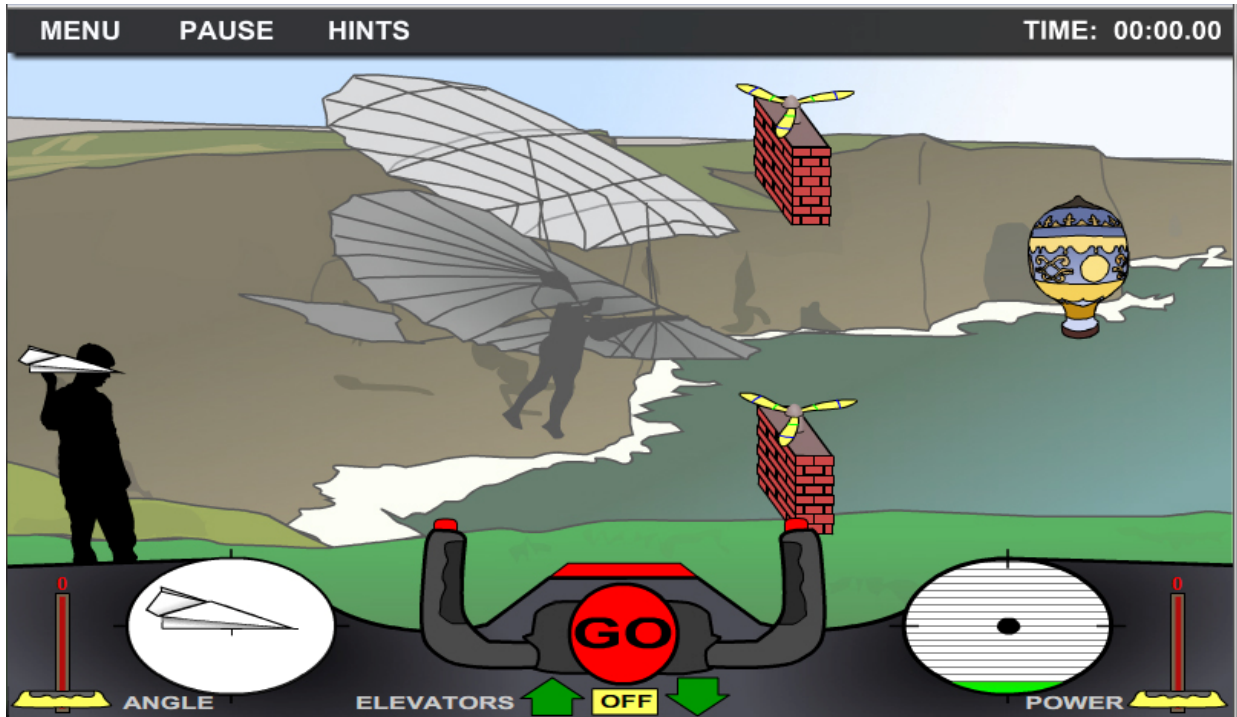


Figure 2: Screen Shot of Flight Path

Overall Recommendations

We have proposed recommendations for the Science Museum in London. The recommendations were divided into two categories: recommendation for our developed prototypes, as described above and general recommendations for the Science Museum. One general recommendation for the Science Museum in London is that we recommend the museum to further develop our proposed resource of the Mars or Lunar Lander that could not be developed due to time constraints. The Mars or Lunar Lander would be used as classroom resources where students would be give a budget to construct a Lander. The purpose of the Lander would be to house a clay figurine that would have to survive a drop. This resource would provide links to the Space Exploration and Gravity units in the UK curriculum along with being an open-ended investigation based activity. We also recommend creating a resource to describe Earth's tilt and how it causes the seasons, creating a checklist of common mistakes and a level sheet, and developing an interactive Flight Kiosk for the Flight Gallery.

These resources will help strengthen the position of the Science Museum to promote science education in the twenty-first century and reach their goal of providing all students in the UK with a Science Museum by the year 2012.

Authorship Page

Team: Everyone on the team was responsible for the editing of the paper and the development of the activities and resource ideas.

Main Contributions of Jake Cabrera

Writing of:

- Background Sections
 - Online resources
- Methodology Sections
 - Research Questions
- Findings
 - Teaches Uses and Needs for Resources
- First Draft of Conclusion
- Teacher Notes

Organization:

- Scavenger Hunt
- Appendix Section

Main Contributions of Alyson Talbot

Writing of:

- Abstract
- Executive Summary
- Introduction
- Background Sections
 - UK curriculum
 - Learning Department
 - Museum's Importance in Education
 - Teacher Resources
- Methodology Sections
 - Introduction
 - Project Design
 - Prototype Testing
- Findings Section
 - Students Engagement section
- Design Sections
 - Introductions to section and subsections
 - Classroom resources guidelines
 - Classroom resources

- Second draft of Conclusion
- Recommendations
- Teacher Notes

Organization:

- Bibliography
- Final Draft

Main Contributions of Jon Tashman

Writing:

- Background Section
 - Space and Flight Galleries of London Science Museum
- Design Sections
 - Flight Path Guidelines
 - Flight Path

Development:

- Flight Path
 - Programmer
 - Assembled User Interface

Main Contributions of Jon Zoll

Writing:

- Introduction
- Background Sections
 - Space and Flight Gallery
- Design Sections
 - Museum guidelines
 - Spinners
 - Advertising Campaign/ Newspaper Article

Development:

- Template Designs
- Flight Path
 - Graphic Designer
 - Audio

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1.0-Introduction

Science is a competitive and world-wide industry, which makes scientific innovations especially important. Companies and countries are competing to create the newest and greatest invention in science by investing money into the research and development of general science advancement. The United States for example has increased funding for research and development in general science by 5.3% over the past year (National Science Foundation, 2008). In the United Kingdom, there is a shortage of students who are pursuing further education in the field of science. In order to promote careers in science, the UK Parliament Select Committee on Science and Technology has made several recommendations. Recommendation 25 states, “The Government should consider measures to promote scientific careers to people of all ages, for example, by using advertising campaigns such as those used to improve the image of teachers, policemen and recruits for the armed services” (United Kingdom Parliament, 2008). If people become interested in science at a younger age, there is a better chance they will continue to pursue science at a higher educational level when they are older. The UK Parliament Select Committee on Science and Technology also made recommendations pertaining to stimulating student demand. Recommendation 24 explains that the only way to secure high levels of future students in higher education science programs is by exciting them in those science topics at an early age (United Kingdom Parliament, 2008). A great way to stimulate the overall interest of students in science is by visiting a science museum.

The Science Museum in London, as shown in Figure 3, is a place where exploration of science meets education in science. The goal of the Science Museum in London is to help guide students with an exciting informal style of education, and to be the number one informal education institution in the UK



Figure 3: Science Museum in London

within ten years (Science Museum in London, n.d.). Another goal of the Science Museum in London is that by 2012, every child in the United Kingdom will have a Science Museum experience. The experience can be visiting the museum, playing one of their online games, using a Science Museum resource, or even being taught something by a teacher who attended a Science Museum course.

Many of the visitors of the Science Museum in London are UK students visiting as part of a school day trip. One of the issues of the museum was engaging students during their visit to the Science Museum and their studies in the classroom. Another issue was the integration of what is taught in the classroom with what is presented at the Science Museum.

The Science Museum provides resources and activities for teachers to help them explain complicated topics in science. Integration of what is presented in museums into the atmosphere of a classroom could benefit students' educational value (Jarvis, 2004). For example, Jarvis (2004) states that there is an importance for quality classroom prep, activities within the museum, and follow-up activities. There are four topics that are significant in having an effective visit to a science museum, which are science enthusiasm, science in social context, space interest, and planning and teamwork (Jarvis, 2004). Though general studies have been done to understand the importance of museum and classroom integration, the Science Museum in London has not completed any specific research relating to their resources and their effectiveness in engaging students.

The Science Museum in London provides resources for teachers to use before and after their visit to the museum. These resources include ideas for interactive activities, experiments, and games which are related to certain science topics. However, these resources do not cover all science topics, including outer space and flight (Science Museum in London, n.d.).

The goal of the project was to establish useful teacher resources that would engage Key Stages 2 and 3 students in the UK science classrooms and within the Space and Flight Galleries. Based on the teachers wants and needs for resources and students engagement in science, which was accomplished through teacher interviews and past science research, the guidelines for the resources were developed. These guidelines were that they were easy to do, entailed little prep time, contained teacher notes, used

inexpensive materials, and were hands-on and interactive to interest the students. The resources created for use in the classroom and in the Space and Flight Galleries allowed students to be engaged in the classroom and during a visit to the Science Museum in London. The resources developed were called Balloon Rocket, Circus Activity, Spinners, Scavenger Hunt, and Advertising Campaign. An online flight interactive game was also created, called Flight Path. Flight Path taught students about the science of flight, history of flight, and related that to the Flight Gallery. These teacher resources can be used in the classroom and during a museum visit that help explain difficult topics within Space and Flight. The development of teacher resources promotes science education throughout the UK, which can lead to students further pursuing science education.

2.0-Background

The London Science Museum preserves and displays various artifacts, including replicas of the Hubble Space Telescope and part of a Boeing 747, within the context of history. It aims to inform and educate visitors of the importance of the milestones through exhibitions and the principles of which they were developed from. One important target audience is children; a group that often visits as a part of a school trip. One specific age group, ages 7-14, is referred to as Key Stages 2 and 3 by the UK curriculum, which mandates the study of subjects including Space and flight. Space and flight are continually studied throughout the UK curriculum by students specifically in the areas of solar system, gravity, and air resistance. These topics are expanded in the Space and Flight Galleries in the museum through traditional and informal education methods, such as hands-on and interactive exhibits. A museum objective is to allow students to understand concepts that are difficult to convey in the classroom setting through informal education methods. With further integration of the museum with the classroom this goal of the museum could be achieved.

This background chapter will discuss the objectives of the UK curriculum of science in Key Stages 2 and 3 in the topics of Space and flight. Next, the museum's importance in education will be discussed. We then focus on what the Learning Department of the Science Museum, Space and Flight Galleries of the London Science Museum present to the students. Lastly, we will focus on teacher resources such as their main use, constraints, and a specific type of resources, online resource.

2.1-Overview of the UK Curriculum

The United Kingdom has detailed guidelines and standards for children's education for each age level, as appropriate. The United Kingdom has two main goals for the education of their students through the curriculum. The first goal is to provide opportunities for all children to learn and achieve. The second goal is to promote students' spiritual, moral, social and cultural development, as well as to prepare all students for the opportunities, responsibilities, and experiences of life (Qualifications and Curriculum Authority, 1999).

To achieve these goals the UK curriculum is divided into Key Stages. There are four Key Stages within the curriculum, as shown in Table 1 (Qualifications and Curriculum Authority, 1999). After the completion of Key Stage 2 and Key Stage 3 students participate in national exams (Balls, 2007). One of the major components of the curriculum throughout each Key Stage is science.

Table 1: Definition of Key Stages

	Key Stage 1	Key Stage 2	Key Stage 3	Key Stage 4
Age	5-7	7-11	11-14	14-16
Year Level	1-2	3-6	7-9	10-11

2.1.1-Basics of Science in Key Stages 2 and 3

In the UK, students in Key Stages 2 and 3 are introduced to many new aspects of science. The science curriculum in the UK consistently focuses on building on previous knowledge, relating topics to everyday experiences, and students being able to investigate topics on their own. The overall objectives of the science curriculum were examined in order to understand the development of Key Stages 2 and 3 students in science.

The objectives and goals of the science curriculum for Key Stages 2 are clearly laid out by the Department for Children, Schools, and Families. First, the links between causes and their effects is explored (Qualifications and Curriculum Authority, 1999). Second, students are expected to begin to develop new processes and skills. The hope is that students begin to develop skills of, “predicting, asking questions, making inferences, concluding and evaluating based on evidence and understanding and use these skills in investigative work” (Department for Children Schools, and Families, 1997). Third, it is expected that students expand their mathematical skills, such as counting, measuring, interpreting graphs in real context, and many other practical math skills (Department for Children, Schools, and Families, 1997). Fourth, teachers are expected to provide the opportunity for students to develop an understanding of scientific processes and skills, and relate them to the child’s everyday experience. Fifth, the Department for Children, Schools, and Families believes the students should be curious about their observations, and investigate them with all of their senses. Lastly, the students should start to connect

the key scientific ideas they learn and connect them to other phenomenon within their life, and attempt to explain why those experiences occur. The knowledge and skills that are developed in science during these school years are built upon in Key Stage 3 (Department for Children, Schools, and Families, 1997).

Besides building on previous topics in Key Stage 2, the science curriculum for Key Stage 3 has other aims. First, students begin to debate the advantages and disadvantages of scientific and technological development and participate in individual and group investigations. Students are then expected to be able to define the significance of the investigations. An example of this is in the unit of Cells in the lesson of “What causes pollen tubes to grow?” After completion of an experiment with pollen tubes students are expected to understand and define the importance of sampling in investigations. Second, students should be able to take their experience and understand its use in the professional world by studying how professional scientists work and the importance of their work (Department for Children, Schools, and Families, 1997). Overall, the main skills students should enhance during Key Stage 3 are their investigative skills and use of the scientific method.

2.1.2- Space and Flight in Key Stages 2 and 3

Although the UK curriculum covers all areas of science throughout Key Stages 2 and 3, the focus of this study is on the topics of Space and flight. The UK’s curriculum has defined specific topics for the fields of Space and flight appropriate for learning within each Key Stage. Within each section of the Space curriculum there are experimental and investigative goals for the students to obtain. The advancement of students’ knowledge in the Space curriculum is a progressive method that builds on previously discussed topics. An example of this is the development of knowledge about the Earth and its rotation from the unit in Key Stage 2, called Earth, Sun, and Moon to further development of the significance of the Earth’ rotation in the unit of the Solar System and Beyond. Although the UK curriculum doesn’t have a unit based strictly on flight, throughout many other units such as Forces in Action, Friction, Forces and Their Effects, and Speeding Up there is a relationship to concepts based for flight (Department for Children, Schools, and Families, 1997).

2.1.2.1- Space in Key Stages 2 and 3

Key Stage 2 includes one unit relating to space, which is titled “The Earth, Sun, and Moon.” In this section teachers explain the relative sizes, shapes, and movement of the Earth, sun, and moon. Some specific topics taught in this section are:

- the changing position of Sun, the movement of the Earth
- the Sun at different times of the years, and the Earth’s and moon’s orbits
- the Earth, Sun, and Moon are spheres.

As an activity to understand the relative size of those spheres students are asked to choose three spheres that represent the Earth, Sun, and Moon. An example is choosing the Earth as a pea, the Sun as a beach ball, and the Moon as a bead. This allows students to see the relative difference in size between the three masses. The objective is for students to make observations and be able to identify patterns within the data sets. This is intended to also help learn how to relate common day phenomena to the information observed in this unit, such as length of a day or the year (Department for Children, Schools, and Families, 1997).

Key Stage 3 expands on the unit in Key Stage 2, in two main units: 1) Space, Solar System and Beyond and 2) Gravity and Space. The Solar System and Beyond unit addresses the concepts of:

- eclipses
- the seasons,
- the Sun as a star emits light

The experimental and investigative skills utilized in this unit are using models to explain topics, to create inquiry on how data of the solar system has been collected and evaluated, to present data graphically, and examine value of the evidence attained.

In the Gravity and Space unit students learn about the phenomena of gravitational pull and what it depends on. Students begin to link the movement of planets to gravity and study space exploration. The investigative skills in this portion of the curriculum focus on how scientists collaborate to collect and examine data from space, how to make predictions from certain patterns, and to consider and assess contradicting data (Department for Children, Schools, and Families, 1997). Students in the UK learn about

all realms of science along with space. The students learn about the forces that act on the Earth such as air resistance, which plays a direct role in the area of flight.

2.1.2.2- Flight in Key Stages 2 and 3

Science in Key Stage 2 covers two areas relating to flight, Friction and Forces in Action. Although neither of these units directly discusses flight, their knowledge of air resistance and forces can be applied to the area of flight. In the unit of Friction, the basics of air resistance are covered, which is relevant in the study of flight. Students begin to develop the understanding that objects in the air have forces acting upon them. An experiment done within this unit investigates parachutes. Students are asked if the size of the parachute affects the speed it takes for a parachute to reach the ground. Students assume that the only force acting upon the parachute is air resistance. This experiment and unit allows students to begin to develop an understanding of air resistance.

In the unit Forces in Action students investigate the effects of forces when they act on an object. There are many forces covered in this unit including the aforementioned air resistance. The objective for the students is for them to comprehend that air resistance slows moving objects and that it acts in the opposite direction of falling objects.

Students in the UK are expected to be able to continually build upon their previous knowledge, and for that reason the topic of forces is continued through Key Stage 3 (Department for Children, Schools, and Families, 1997). In Key Stage 3 two units, Forces and Their Effect and Speeding Up, focus on forces, specifically in air resistance. In the unit Forces and Their Effect students are taught to identify the origin of forces, use the idea of speed, and understand when forces are balanced and unbalanced. In one part of the unit students are asked a series of questions about what forces are acting on objects during certain situations. One situation asks what the effect of crumpling paper has on the speed of the paper as it drops from the air. This experiment asks the kids to associate the change in speed with air resistance.

The other unit that focuses on areas relevant to flight is Speeding Up where students learn more about the concept of speed, relationship between forces, and the effect of certain forces on speed. In the topic of how forces effect speed, student begin to understand that force produces a change in speed and that without those forces the speed

would be steady or nonexistent. In developing that knowledge students begin to understand that air and water resistance both slow down speed and are the opposite of motion.

In further investigation on the topic students begin to draw a direct relationship between air resistance and speed. By increasing speed, the magnitude of air resistance also increases. In the final topic of this area students investigate the topic of parachutes and how they work. Students watch a video of a skydiver and describe the forces acting on the parachute once it is released. Overall in Key Stage 3 students form a true understanding of forces, their effects, and relationships (Department for Children, Schools, and Families, 1997).

In summary, the UK Curriculum in science aims to have students develop their scientific knowledge. This is to be accomplished with guidance from the teacher as well as, through students' own investigation into ideas, which are tied to their everyday experiences (Qualifications and Curriculum Authority, 1999).

Although the UK classrooms use models and experiments to help students understand the topics of Space, another useful way to help students learn is by a visit to a science museum. On a visit to the Science Museum in London students can explore the Space and Flight Galleries to expand on their knowledge of space and flight.

2.2- Museums Importance in Education

The purpose of museums is not only for displaying the progress of humanity, but to educate how this progress was achieved through innovative representations. Throughout the school year many students, of all ages, visit museums to expand their knowledge. In fact, it has been stated that museums have become an essential part of the educational infrastructure (Rennie, 2006). The importance of integration of classrooms with museums is clearly explained by Mortensen (2007):

The importance of supplementing formal science education with museum visits is acknowledged not only by the U.S. National Research Council, which states that 'the school science program must extend beyond the walls of the classroom to the resources of the community' (National Research Council [NRC, 1996]), but also by museums themselves, for whom education has long been an integral part of the mission statement (Mortensen, 2007, p. 1).

Mortensen (2007) explains that the motivation for students to learn in the museum is intrinsic, which is when learning takes place for its own sake because the student is interested in the subject matter and enjoying his or herself. Museum visits have been shown to result in refinement of already existing knowledge along with creation of new knowledge (Mortensen, 2007).

One of the more effective ways museums educate and motivate their visitors is through interactive and activity based experiences (Storh-Hunt, 1996). Storh-Hunt (1996), found that students who experienced hands-on activities either everyday or once a week scored higher on standardized tests than the students who rarely experienced hands-on activities within the classroom. Also, the use of an activity based curriculum adds emphasis to the ways and means of science, independence in learning, creativity, and problem solving (Bredderman, 1983).

One can draw a parallel between the activities used in the UK curriculum and the Science Museum in London. As previously discussed, the UK curriculum uses experiments and investigations to teach students in the area of science. The Science Museum in London's goal is to inform and educate visitors of the importance of scientific milestones and the principles of which they came from through exhibitions. The museum uses hands-on activities within their exhibits, to help students absorb information and stimulate their interest in the subject matter (Science Museum in London, n.d.). The parallels are especially noticeable since the Science Museum in London has started to implement interactive exhibits to stimulate and capture the visitors' curiosity on the subject matter.

2.3- Science Museum in London Learning Department

The Learning Department of the Science Museum in London offers many options in terms of events and resources for educators. Their mission is to, "actively engage and inspire all audience, especially new and diverse audience, in science, industry, and media through our unique collections and interactive programmes and experiences" (Upton-Swift, 2007). Their target audience is mainly students and educators throughout the UK. The Learning Department of the Science Museum has a goal to be the number one in

providing unconventional educational programs to audiences within in the UK and throughout the world.

The Learning Department uses six key words to describe their guidelines and goals, Anticipate, Explore, Connect, Reflect, Share, and Return. Each word is used to describe an important stage in achieving the mission of the Learning Department, which is engaging audiences in science through a Science Museum experience. A Science Museum experience is described as more than just a visit, it describes any encounter with the museum, such as using their online resources or being taught information from the science museum through a teacher who attended one of the Science Museum's courses (Upton-Swift, 2007).

Anticipate is a key word that describes the idea of preparing audiences for a Science Museum experience, which can be achieved by stimulating or sparking the audiences' interest and curiosity. Explore and Connect are used in tandem with each other. Explore and Connect explain that exploring the Science Museum experiences invoke questions, excitement, discoveries, enthusiasm, and new understandings about science, society, and their connection to each another. Reflect and Share are also used together. Reflect refers to being able to reflect back on the experiences and be able to put them into relevant context. Being able to share those reflections reinforces learning and helps change the current attitude of audiences toward science and the Science Museum. Lastly, Return means that the experience inspired the audience to want to continue returning to the Science Museum and its available experiences (Upton-Swift, 2008). Using those steps the Learning Department is hoping to create more interest in the Space and Flight Galleries of the museum through the results of this project.

2.4 -Space and Flight Galleries of London Science Museum

When at the museum, there are several exhibits that students within Key Stages 2 and 3 can explore. The museum offers several galleries that would be visually beneficial for students so that they can understand topics in a more lifelike manner as opposed to seeing the same thing as a small picture in a classroom textbook.

Location of a gallery is essential for the success of that gallery within a museum. A good location will have a significant amount of traffic flowing in and out that will

allow the exhibits inside to have maximum exposure. An ideal location would be in an area that people would have to pass through, is easily accessible, and is visible from other parts of the museum (Upton-Swift, 2008).

Location is significant for both the Space and Flight Galleries. The Space Gallery is located on the ground floor of the museum and is part of the museum's central artery. Because of its location, it is a high traffic area, and as such most visitors will visit or at least pass through the gallery. It also benefits from having a direct relevance to the UK Curriculum, making it a likely stop for many of the 2500 students who visit the museum a day. The Flight Gallery faces a different problem as it is located on the third floor of the museum towards the back end of the museum. The gallery is obstructed on both fronts by blocked corridors and uneven floor levels. The gallery is not a pathway to any other exhibits, which means the gallery mostly attracts people who previously planned on visiting it (Upton-Swift, 2008).

The Exploring Space Gallery is one of the most up to date galleries within the museum. It contains a varied display of rockets, satellites, and space probes. The gallery attempts to address such topics as the start of the space age, the launch of satellites into space, and spacecrafts sent to other planets. They also display the composition of rockets which is



Figure 4: Black Arrow in Space Gallery

supplemented by two authentic space rockets hanging from the ceiling of the gallery. One of the rockets hanging from the ceiling is the Black Arrow R4 as shown in Figure 4. Replicas are common throughout the gallery, including models of the Hubble Telescope, SOHO, and AMPTE satellites. The students can learn what various satellites are used for and why they are important to subjects of science, such as weather and the study of stars which is

easily integrated with their Key Stages 2 and 3 studies. They also have replicas of the Eagle Lander and the Huygens Lander along with the SOHO and AMPTE spacecrafts that were used to understand the Sun (“Science Museum”, n.d.). In addition to the various pictures and objects on display, the Space Gallery has one digital exhibit called “What Have We Sent into Space?” that helps visitors understand the scale and scope of what man made objects are currently in orbit. It displays a video of the Earth close up with a few specks flying by and then zooms out to show a plethora of specs, with each spec representing a man-made object that was sent into orbit. There is also an interactive monitor, which describes that different type of man-made objects that are currently in orbit (N. Upton-Swift, 2008).

The Flight Gallery focuses on displaying exhibits that demonstrate both British and international progress and accomplishments in aviation. The aircrafts presented in the gallery range from the dreams of flight

during the Renaissance age to the jet of today. One of the most authentic Antoinette monoplanes in the world is displayed within the gallery. Other exhibits consist of Supermaine S6B racing seaplane, the Hawker P1127, and as shown in Figure 5 a complete piece of a Boeing 747 jet that is sliced open to demonstrate the composition of an airplane. The gallery also shows various small scale models of aircrafts and aviation engines from all different types of aircraft (“Science Museum”, n.d.).

These models might also spark the interest of the students to wonder how a bird can fly and a plane that weighs a great deal more than that of a person can also fly, yet people cannot. This could lead discussion and understanding of lift and other science components that cause the phenomenon of flight.

Figure 5: Cross-section of a Boeing 747



2.5-Teachers Resources

A school visit to a museum can be an effective way to supplement topics learned in the classroom. The teacher's organization and interest in the visit will directly affect the type of visit their students will have (Jarvis, 2004). Specifically, the quality and use of activities before, during, and after the visit are important aspects to a successful visit to the museum. Three approaches can be made to make learning more enhanced at a science museum:

- increase students familiarity with the museum
- ensure students have appropriate levels of knowledge about the topics and focus of the exhibits and activities, and
- provide prior opportunities for students to practice relevant skills (Lucas, 2000).

The pre-visit lesson can generate excitement for the students before their visit, familiarize them with the museum, and give an overview of what the visit to the museum will entail (Lucas, 2000). Jarvis (2004) describes that the purpose of the visit should be told to the students; that the visit is for educational purposes and not just a recreational day off from school. It will also allow students to practice skills that will optimize their involvement in any activities that could take place at the museum, so students can become comfortable with participating in activities at the museum (Jarvis, 2004).

During the visit to the museum the main resources teachers use for their students are worksheets. (Mortensen, 2007) Worksheets illustrate and ask questions about certain exhibits that teachers want the students to observe. A worksheet attempts to engage the learner while maintaining the museum's identity as a free-choice learning center. The worksheets should entail clearly defined goals, tasks in balance with students' ability, and open-ended learning opportunities. Since most museum visits should have students broken up into groups, the worksheets should also involve group aspects. Some of these group aspects for the worksheets are multi-user and multi-outcome that will spark group discussions between the students (Mortensen, 2007). See Appendix A for an example of how to construct a proper worksheet. The problem with worksheets is that all students may not enjoy them. Students do understand though that without worksheets little would

be accomplished. During an interview with students by Griffin (2004), a student said, “...but you wouldn’t learn anything if you didn’t” (Griffin, p. 6, 2004).

In order to wrap-up what was learned and accomplished during the museum visit, a post-visit lesson should be used. A great way to do this is by assigning activities and tasks on the worksheets to be completed after the visit to the museum (Mortensen, 2007). Another example of a post-visit lesson is to have a classroom discussion on why certain exhibits interest them and if they connected to previous discussed topics in class. Such post-visit lessons allow teachers to remind students of what was accomplished during the visit (Lucas, 2000).

2.5.1-Online Teacher Resources

Over the years, online resources have become educational tools that have engaged people to explore and learn. Online resources have allowed for the creation of learning communities that are unbound by time or location, providing knowledge to those that found it difficult to obtain before. By learning through online resources, the educational values that will be experienced by students can potentially enhance learning as a whole (Kerrey & Isakson, 2000). Owston (1997) stated that the internet can free teaching and learning from the physical boundaries of the classroom, and that traditional lectures and demonstrations can become internet based multimedia learning experiences (Owston, 1997).

The Science Museum in London has produced one online resource that has

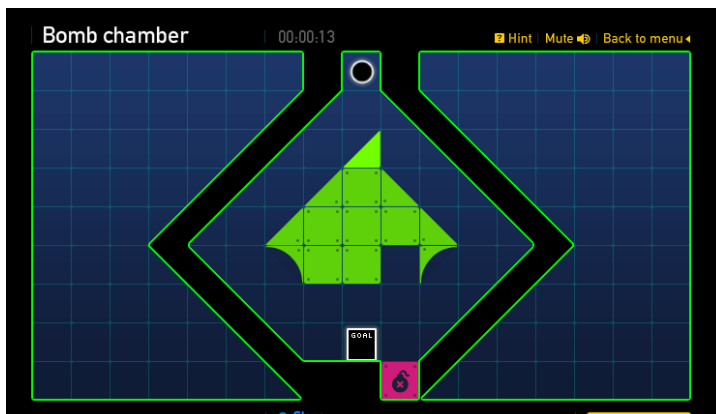


Figure 6: Screen Shot of Launchball

engaged its visitors, by providing simple yet powerful demonstrations of various topics within the world of science. The online resource is called Launchball, a screen shot of the game is displayed in Figure 6. The setup of Launchball is simple, that is it

is both maneuverable and easy to command. The game provides a range of difficulty,

which allows it to suit the varying abilities of students. Each level entails a set of obstacles that require the use of certain tools in order to complete it. In order to use the tools effectively one must understand, basic science concepts, such as air, electricity, heat, forces, motion, water, and light. Without obtaining this knowledge, the levels would be far more difficult to complete. This is what makes Launchball so effective because it incorporates the science taught in the classroom along with what is taught within the Science Museum. Launchball though does provide clues to guide the user in the right direction, which promotes and teaches the user the science concepts found in the game. Once each level is completed, Launchball provides a small window with valuable information related to the level that was just completed. This information entails facts about the science topics mentioned before, educating the user more about the purpose and effect of the certain science topics. This leads to the final feature of Launchball, the creation of user levels. This feature allows any user to design and construct various levels of total originality, testing the knowledge and creativity each user obtained while playing the game (“Science Museum”, n.d). Although, Launchball is a successful teacher resources in general there are restrictions to teacher resources and how they are implemented.

2.5.2-Constraints of Teacher Resources

Although it seems that resources are an effective and popular way to supplement a visit to a science museum, not all teachers use them. The main factors that affect their decisions are personal biases and technological constraints

Some teachers have tried to implement science resources, but they personally found them to be ineffective (Lucas, 2000). An example of teacher bias is described by Lucas (2000) who interviews a teacher that explains to him that she refuses to use resources during a visit to a museum because she believes the use of anything other than the exhibits takes away from the children’s learning.

Other teachers may have trouble implementing various aids because of technological constraints (Wilson, 2003). For example, if one resource exists as an online game, the computers may not be fast enough or have the proper software to run it. Since

most resources are online the teachers with technological constraints will not even know about the existence of these resources (Wilson, 2003).

2.6- Summary

Our main area of focus is to understand how science museums can have a positive influence on students' knowledge of science. This requires the integration of UK science curriculum and the Science Museum in London referring to units in the UK curriculum, museum importance in education, and the goals of the Learning Department of the Science Museum in London.

In Key Stages 2 and 3 students learn a variety of science topics, including ones relevant to the area of Space and flight. The Science Museum in London has two galleries that directly relate to these topics, the Flight Gallery and the Space Gallery. These educational experiences allow students to see Space and Flight topics from a different angle, which is essential in finding out how to transition into a productive atmosphere.

However, teachers do not have access to high quality resources that will enhance or integrate the UK science classrooms with the Science Museum in London. The current teacher resources for the Science Museum in London are posted on their website, but one of the biggest constraints of teacher resource use is technology. The resources describe activities and games teachers can use to tie the material covered in the museum visit into the classroom. These resources vary depending on the Key Stage.

For Key Stages 2 and 3, the resources cover a limited set of topics. For Key Stage 2 the topics are light, sound, electricity and magnetism, forces and motion, and materials. For Key Stage 3 the topics are light, materials, electricity and magnetism, and energy transfer (London Science Museum, n.d.). Thus, steps could be taken to fill the information gaps currently presented in the body of teacher resources.

3.0-Methodology

The goal of this project was to develop teacher resources for Key Stages 2 and 3 on the topics of Space and Flight that can be used in the classroom or in the Science Museum. The achievement of this goal could lead to more students being stimulated in the field of science and pursuing a career in science.

In order to create teacher resources related to Space and flight that were integrated into the learning outcomes of Key Stages 2 and 3 in the UK curriculum, we investigated the following questions:

1. What resources do Key Stage 2 and 3 teachers find helpful for use in the classroom or during a visit to the Science Museum in London?
 - Understanding what type of resources teachers used in the classroom and during a visit to the Science Museum in London allowed the team to use this information to ensure our resources fit the needs and wants of teachers and that the resources will be effective.
2. How are students engaged with the exhibits in the Space and Flight Galleries and how does their interest vary based on individual culture and gender?
 - Understanding what students enjoyed within the Space and Flight Galleries and how those interests differ between gender and culture allowed us to develop well rounded resources for all genders and cultures that also covered topics that engaged the students.

Information about these issues helped the development of effective teacher resource prototypes that will help incorporate the UK curriculum into the Science Museum in London. In the following sections, we discussed how we obtained data to achieve our objectives.

3.1- What resources do London science teachers find helpful for use in the classroom or during a visit to the Science Museum in London?

To determine what resources help teachers create a bridge between the classroom curriculum and the Science Museum in the areas of Space and flight, we identified the factors that influenced their decision by interviewing teachers of students in Key Stage 2 and 3, conducting historical research, and visiting and reviewing resources currently implemented by the Science Museum or other museums.

3.1.1 Teacher Interviews

To identify the factors that affected their use of different type of resources, we conducted interviews with these teachers while they attended the Science Museum (See Appendix C). We selected the teachers by using the Educational Booking Office's resources, which had details on each class visiting the Science Museum. The criteria we chose for selecting the teachers to interview were:

- that they taught students of Key Stage 2 or 3,
- they were visiting the Science Museum on March 19 or 20
- their would be a convenient time to interview them

A convenient time to interview a teacher was when a class planned on attending an event in the Theatre or the Energy Gallery. At these two events, students were engaged or were waiting to begin their planned activities. Therefore, the teachers had time to talk with us instead of feeling overwhelmed with the responsibility of watching over their students. Due to time constraints in our project, this was the best way to gather as many teachers as possible to perform interviews at the Science Museum.

The questions that we asked teachers (See Appendix B) related to what resources they found useful. We also asked about the limitations of their existing resources and what they wanted to see developed in new resources for the Science Museum, primarily in the Space and Flight Galleries. However, due to the size of the school groups, we found it difficult to obtain detailed answers from some of the teachers we selected since their attention was pre-occupied with caring for their students. Throughout these interviews, we recorded the answers the teachers gave so as not to misinterpret or leave out anything they said. These recordings were later written down to summarize the interviews, but the original recordings were held onto for reference. This allowed us to determine similar trends or differences in how the teachers answered each question.

Unfortunately, some of the teacher recordings were hard to interpret from all of the surrounding noises projected by the students at our location.

As for our data collection, we conducted a qualitative analysis that focused on the views of the teachers. Since each teacher had different views on particular topics they taught, it was important for us to distinguish what were reasonable assessments the teachers provided in their interviews. This ensured that our development of these resources for Key Stages 2 and 3 were accurate and efficient. The views of the teachers who seemed more attentive and available to talk were weighed heavier than those who were constantly turning around to talk to their students or check on them.

3.1.2 Historical Research and Interviews with Science Museum Staff

We also used previously conducted research by the Science Museum's research team to identify what resources teachers found helpful. This historical research consisted of three articles: "Talk Science", "Teachers and Websites", and "Educational Group Visits to the Science Museum". This research pinpointed at what teachers enjoyed from using resources in terms of practicality, education, organization, communication, and maneuverability. It also concentrated on how teachers felt about online resources, observing the different opinions each teacher had about its usage.

Another method we used was meetings with our sponsor, the Manager of Teachers' Resources, Courses and Visits, Nicola Upton-Swift. We asked her questions relating to what teachers found to be successful resources, and through her expertise she provided information on effective teacher resources.

3.1.3 Review of Teacher Resources at the Science Museum and other Museums

To understand the current use of resources, we studied and evaluated resources of the Science Museum and other museums. The Science Museum provided us with many different types of resources to evaluate in general and also resources specifically related to the topics of Space and flight. We visited the Tate Modern to view their teacher resources in their gift shop, and evaluated the schools that were visiting the museum that day. Other museums resources, specifically museum worksheets, we looked at to evaluate were the Imperial War Museum and the British Museum. The analysis of all these

resources was used to study and understand the format of resources, and what is necessary to develop and construct an effective resource. These examples of resources provided the team with guidelines and examples of well done and poorly constructed resources.

3.2- How are students engaged with the exhibits in the Space and Flight Galleries?

We measured the level of interest in certain exhibits of the students. Since our sample for this question was students in Key Stages 2 and 3, we felt that our interviews with teachers in the Science Museum would provide the answer as to how students were engaged. We asked teachers the questions about students' engagement during the same interviews as mentioned before. The teachers were chosen because interviewing students would require us to ask for special permission by their guardian and/or teacher, along with one of the guardians or teachers being present during the interview. This was because we did not have a criminal records bureau (CRB) check, which is required for anyone dealing with children. Since we could not ask students questions, the questions that we asked the teachers related to what activities their students found the most interesting and why, followed by what their students found to be the most interesting in the Space and Flight Galleries.

However, some of the teachers we interviewed did not have the opportunity to visit the Space and Flight Gallery on account of time limitations to their visit, thus we did not get an answer regarding the students' interest. We again recorded the answers that the teachers gave so as not to misinterpret or leave out anything that they said, but the amount of noise generated by the students in the background made it difficult to interpret some of the teachers' answers. We also analyzed the data by using the same qualitative approach as before, except this time we focused on the students' interest in each exhibit. The teachers' answers were also weighed on engagement as well.

3.3- Project Design

Our project design consisted of creating resources that provided activities that would be helpful to teachers to discuss topics pertaining to Space and Flight before, during, and after their visit to the Science Museum in London. A goal for created resources prototypes was to help bridge the gap between the Science Museum and the UK curriculum. This was achieved by making the resources for use in the classroom and the Science Museum, by targeting Key Stages 2 and 3 students, and by making them available online.

The resources we created followed certain design criteria specific to the Science Museum. The Science Museum in London referred to their criteria as the House Template. This template ensured that all resources developed were Disability Discrimination Act compliant, which meant that there is a specific font, size, and color contrast that needed to be followed to ensure that it was appropriate for people with bad eye sight or color blindness. Also, the resources had to contain scientifically correct information and be edited. Another criterion was that the resources were audience appropriate; therefore, the resources had to be suitable for Key Stages 2 and 3 students.

Another factor in developing resources was generating teacher notes for each resource. The teacher notes had a specific set-up according to the Science Museum. These teacher notes involved sections on: *Educational Objective, Key Learning, Materials, Procedure, Practicalities, Open-ended Investigations, Discussion Ideas, Extensions, Links to the Curriculum and Museum, and Links to Everyday Life*. These sections were developed to provide details to the teacher about why this resource was useful, how it connected to what they were teaching, how to successfully do the experiment, and what to do to provoke discussion and thought with the students. The materials for the resources were chosen carefully, to make sure that most materials were inexpensive and easy to obtain for the teachers. All these factors allowed the resources to be easily implemented by teachers. Another way to make sure that teachers would use and enjoy the resources was by testing them.

3.4-Prototype Testing

Creating an ideal resource involved testing of the Space and flight prototypes by the museum staff, teachers, students and ourselves. Team testing was done for each resource developed. These resources were tested to examine difficulty, as well as to test requirements and flexibility of the resource materials. If a resource was too difficult for the team to complete, it could immediately be eliminated since it would not be feasible for students in Key Stages 2 or 3. For the testing of requirements and flexibility, each resource was tested with all different variations of the listed materials. This allowed the team to discover if a certain variation would or would not work for the resource. From that testing, stricter limitations were added to the materials and procedure of each resource.

The student testing was done in an hour and half testing session with a science club of Year 7 students at Bridge Academy in Hackney, East London, whom were asked to participate due to having a previous relationship with the museum. Also, Year 7 (ages 11-12) students is close to the median of the targeted age range of Key Stages 2 and 3, and allowed for use of the basic concepts and some extensions of the resources to be used. The limitation of using only one age group is that there was no understanding of how younger and older students would enjoy and use the developed resources, but mainly due to time constraints only one resource was used. The team spent two hours in the classroom presenting the Balloon Rocket and its extensions to the group. During the testing observations, we attempted to see how easily students were following the instructions and completing the resources, how they were enjoying themselves, and how they understood the educational objective of each resource. In order to see if students learned anything from using the resources, a discussion took place during and at the end of the testing. The observations were then analyzed qualitatively, and the prototypes were altered based on the observations.

Teacher and staff testing occurred during a two hour event that was planned at the beginning of the project. The testing was kept to two hours because of our interview with a museum staff member, Sam Spicer, who informed us anything longer than two hours would be too long to keep the group engaged. Invitations were sent out to specific teachers that have done previous testing with the museum, and specific staff members

were invited who would be interested in the resource development process. Staff members with previous teaching experience were also invited to the testing session. The main limitation for this method was time because teachers could not be given enough advance notice to participate in the testing. For that reason the testing session was compiled of one teacher and five staff members some of whom had past teaching experience. At the testing event the teachers and staff were split into groups. These groups mixed people with teaching experiences and other museum staff members that did not have teaching experience. Each group was observed while creating the resource, and then we analyzed their production and discussion. The resource prototypes were divided into different stations. The museum resources and the Light Upon Earth's Rotation were presented to all members present since we believed those needed the most feedback and suggestions. The testing session was organized by having the groups try out one of the activities, come back together for a discussion on museum resources, having them try out another resource, and finished with an overall discussion (See Appendix BB). The suggestions and feedback from the testing session were then analyzed qualitatively, and certain suggestions were implemented for our final design of the prototypes. .

4.0- Findings of Research

Analysis of the data collected led us to understand what teachers found useful for resources and how engaged their students were in the Space and Flight Galleries of the Science Museum. By conducting teacher interviews and using historical research previously completed by the Science Museum, we were able to formulate what resources teachers found important and effective. We recorded interviews with thirteen teachers overall, varying between Key Stages 2 and 3, and asked questions pertaining to teacher resources, exhibits of the Science Museum, and the Space and Flight Galleries. These interviews also led us to determine what students found most engaging in the Science Museum. The findings in both areas were used to develop teacher resources, described in chapter 5 that should help engage students in the topics of Space and flight.

4.1- Teacher Uses and Needs for Resources

The teacher interviews were used to analyze data on teachers' use and needs for resources (See Appendix B). We also analyzed the historical research conducted by the Science Museum on teachers' uses of and needs for resources. The main findings from these interviews and historical research were that teachers wanted resources that related to the curriculum, were age-specific to Key Stages 2 and 3, and easy to print off and use to avoid time constraints. Teachers also wanted resources that invoked discussion in the classroom, and that were available online. In addition, the teachers found drawbacks or limitations in the resources that they did use.

Among the ten of the teachers we interviewed, two teachers wanted resources, for use in the galleries, that were more hands-on for students. The other eight wanted resources that were more helpful in preparing teachers and students beforehand for the objects they were going to see. Those same eight teachers wanted the resources to be geared towards the curriculum. The historical research by the Science Museum also emphasized how teachers wanted resources that related to the curriculum. Over eighty-two percent of the thirty-nine teachers questioned by the museum said the most important reason for visiting the Science Museum in London was that it related to topics covered in the curriculum. From the data it showed that the trip must have curriculum relevance if

teachers are going to consider a museum trip. These observations led us to develop resources for the Space and Flight Galleries that were specific to the curriculum of Key Stages 2 and 3.

As for the limitations of resources, teachers found that time constraints played a major role when using several resources. Their schedules were planned out for most of the day, so taking the time to search for a resource that was helpful in educating students was unrealistic. Teachers often looked for resources that had clear educational objectives. For example, Talk Science, one of the Science Museum's Research and Advocacy Groups, ran a course for teachers in the Fall of 2007. The teachers present at the course appreciated how the course provided a wide range of ready-made ideas and activities that teachers could use immediately; therefore, developing resources that were clear in their educational content would allow teachers to use them without interfering with their busy schedules. This was important because teachers often dealt with time constraints throughout their work with students, a recurrent theme from our interviews.

Another limitation for teachers, primarily in Key Stage 2, was that resources were not age specific. Six teachers said that they had trouble adapting the resources to fit their students' age group; existing resources were either too difficult for the perceived age group, or were not connected with the subject they were covering. Thus, teachers tried to alter and adapt the resource into something in the students' curriculum as well as into something the students could follow and understand. This took valuable time that the teachers felt they did not have. Through the historical research, teachers expressed mixed views toward what specific age group the Science Museum's content was targeting. Over eighty-nine percent of primary school teachers, Key Stages 1 and 2, felt that the content in the Science Museum targeted Key Stage 2, where as seventy-four percent of secondary school teachers, Key Stages 3 and 4, felt that the content in the Science Museum targeted Key Stage 3. Therefore, when designing our resource templates, we incorporated activities that were age specific to Key Stages 2 and 3 that avoided this split in age group targeting. This was done by creating extensions for the classroom resources and separate museum resources that were targeted for certain age ranges.

In relation to teachers using resources in general, only ten out of the thirteen said they used general resources. Of the ten teachers that used resources, four said they used

resources that were compatible with interactive whiteboards, three said subject-specific resources, two said they used worksheets, and one said a vast variety. In terms of using resources for visiting the Science Museum, only three out of the thirteen teachers said they created or used resources for their visit on the day of the interview. However, seven teachers from the ten that used resources did not want to use ones that were not quick to prepare and set-up with students, which coincides with their issues of time constraints. Since they use interactive whiteboards and worksheets most frequently, we designed several resources as worksheets along with ones compatible with interactive whiteboards to make them convenient for teachers to use. Therefore, we developed our resources with templates that only required printing; for this reason, teachers will not need to excessively prepare for our designed resources.

From the historical research, we found that teachers want resources that often generate discussion with their students. One example was from the Talk Science course for teachers in the Fall of 2007. Teachers liked seeing ways where discussions in the classroom could be achieved with students, such as using different activities, methods, and example formats. This led to our resources having discussion questions and extensions that required students to think and process ideas that they may not have understood before.

Another aspect of previous research was that teachers often use museum websites as resources. Museum websites were often used by teachers because they found them to be effective and reliable. The Science Museum's Research and Advocacy Group conducted a study on teachers and their general use of museum websites. They determined that teachers used museum's websites because they found practical information relating to planning visits, information and content relating to the museum or galleries, and resources that focused on the museum or gallery that could be used before, during and after a visit. As for the use of websites in general, teachers revisited websites that were useful, relevant, and valuable for future references. According to the Research and Advocacy Group, these websites were very useful because they related to the curriculum, both in content and structure, and were formatted so they were easy to print off and use. Teachers did not want to waste time looking for relevant information that was not easily presented. Due to their time constraints, they would rather search for

another site with similar content that was easily presented to them than waste important class time searching for one where some surfing was required. Therefore, having clear and simply formatted resource templates incorporated into the Science Museum's website would be ideal. This would allow teachers to prepare for their activities in very little time, resulting in a greater opportunity to use class time appropriately. This could also be an opportunity for the Museum to expand on its curriculum content online. Teachers have expressed how the Science Museum already provides excellent curriculum content within the Museum, but covering more on the topic of the Earth Sun, and Moon can be improved. In our design of resources, we emphasized resources that were accessible online and related to the topics such as the Earth, Sun, and Moon.

Overall, the data analysis conducted throughout the interviews and historical research gave us a strong idea as to how we should approach our teacher resource development. By incorporating our resources to be age specific, easy to print and use, invokes discussion in the classroom, made available online, and related to the curriculum, teachers would be able to educate their students in an effective manner as well as interest them within the topics of Space and flight. However, to properly assess the effectiveness of developing these resources, we needed to understand how students were engaged.

4.2- Students' Engagement in Space and Flight Galleries

The teacher interviews were conducted to obtain knowledge about students' engagement in the Space and Flight Galleries. The data collected showed two major findings: time was a major constraint and students enjoy hands-on and interactive activities. Time was the main reason why most classes did not visit the Space or Flight Gallery, but when a class did visit one or both of the galleries; teachers reported they were enjoyed by the students.

First, teachers were asked what general activities students enjoyed the most. Nine out of the eleven teachers stated specifically that hands-on, interactive, and sensory activities were most enjoyed by their students. This data provided us with information about how to engage students, but not how students were engaged within the specific galleries of Space and Flight.

Therefore, six teachers were asked if they had a chance to visit the Space or Flight Gallery, and of those only two teachers had done so. One of those teachers was present in the Space Gallery during the visit, but his students were observing a drama character presented by the Science Museum in the Space Gallery. For that reason, his students' engagement within the Space Gallery could not be judged. The other teacher said her students enjoyed the Space and Flight Galleries, and they enjoyed being able to touch and see planes and rockets up close.

Some teachers were not asked if they visited the Space or Flight Galleries since it was clear from their previous answers they did not have time to plan a visit to either the Flight or Space Galleries. Teachers reported that time was the major constraint during their visit to the Science Museum. Most teachers had a very detailed schedule for their visit, mostly dictated by theater shows, Launchpad and its shows, and an IMAX[®] show. This left classes with little time to explore the rest of the museum. Teachers also tried to go to galleries and shows with direct relevance to what they were studying in the classroom. Many teachers we interviewed went to the "Feel the Force" show, which directly related to the topics of force covered within the science curriculum of Key Stages 2 and 3. Due to the small number of students who specifically visited the Space or Flight Galleries, we were unable to have a broad analysis of what students enjoyed most in those galleries. Nevertheless, it was very clear that teachers visited galleries based on the galleries' connections to the curriculum; therefore, when designing our resources, the link to the curriculum had to be made clear to the teachers.

4.2.1- Differences in Culture and Gender

To understand students' engagement in science and the Science Museum, data was collected on culture and gender differences. We attempted to determine if there was a clear disparity in what different genders or cultures enjoyed within the museum. When interviewed, teachers answered in terms of either gender or culture, but not one teacher gave a detailed answer regarding the differences related to both culture and gender. This we believed was due to the order of questions during our interviews as this was the last question and, therefore, the attention of many teachers was turning to their students and their need to return to their class.

Most teachers responded on differences of gender. Nine of twelve teachers stated they saw no difference in their students' engagement in the museum based on gender. One teacher stated that no matter what culture or gender, "kids are just kids." Five of the teachers who did not see a split were dividing their attention during the interview between constantly turning around to check on their students or rushing through their answers to be able to get back to their class. The two teachers who saw a noticeable split in gender expressed that the boys in their classes were drawn to the things with speed and power, like rockets and engines and the girls were more interested in technology and the intricate details of things.

The most intriguing response to this question came from a teacher in an all-girls school who had previous teaching experience at a mixed gender school. She said that it was not about a difference in gender, but it was more about a range in personalities. She saw the same range in personalities at the all-girls school as she had previously seen in the mixed gender schools, but now girls were taking on the more outgoing roles that the boys usually played in the schools with mixed classes. She believed that without the boys present, some girls took on more outgoing personalities.

Due to the responses from our interviews, we did not see a considerable split in gender. We designed for the gender split when necessary, but it did not require as much attention as previously believed.

During our interviews, only one teacher highlighted the differences in culture. This teacher described how one of his students spoke very poor English. This student would not take time to try to read any of the signs in English, but if there was something to watch or play with she would take the time to learn from that. The teacher believed interactive and hands-on exhibits provide equal opportunities for students of all cultures. As a result, we incorporated more pictures and visual concepts than written material into the design of our teacher resources to provide students of all cultures and language backgrounds the same opportunity to complete these activities.

5.0-Design of Teacher Resources

Based on the findings of our research, prototypes for teacher resources were designed and developed for use in the classroom and the Science Museum in London. These prototypes focused on students within Key Stages 2 and 3 on the topics of Space and flight. The prototypes were broken into three categories: classroom resources, museum resources, and the online interactive game. Each set of prototypes had specific guidelines to follow that were developed based on our interaction with the museum staff and our own observations of the Science Museum.

The classroom resources were created to give students hands-on and interactive opportunities. These provided students a way to learn about difficult concepts in Space and flight through a different method than by reading or taking lecture notes. The classroom resources were developed along with teacher notes. These notes guided the teachers through the experiment as well.

The museum resources were created to engage students not only in the topics of Space and flight, but also within the museum. The goal of these resources was to bring students to certain and important artifacts within both the Space and Flight Galleries. These resources were created as dynamic worksheets, allowing teachers the ability to just print out the sheet of paper.

The online interactive game, Flight Path, was developed for use in the classroom, specifically for use on the interactive whiteboards. Since the game was web-based, another potential use of the game would be as a homework assignment for the students to complete on their own time. As the game developed simulated paper airplane flight, it fell under the topic of flight.

5.1 Design Guidelines

The guidelines of our prototypes were proposed by the Science Museum Staff and through our own observations of the museum. Each type of resource, classroom, museum, and online interactive, had its own set of guidelines to follow. These guidelines helped us design the most effective resource for UK teachers and fit the unified theme of the Science Museum.

5.1.1 Classroom Resource Guidelines

The design of the classroom resource prototypes had to fit both the needs of teachers along with the guidelines of the Science Museum. Being able to satisfy both the museum staff and the teachers ensured that the prototypes would be utilized by both groups.

Designs that utilized cheap materials and a clear link to the curriculum were used to fit the expressed needs of the teachers. Through meetings with our liaison, Nicola Upton-Swift, we learned that teachers wanted detailed teacher notes with each activity. These teacher notes guided them through the experiment, and minimized the amount of prep time.

The teacher notes entailed sections on *Key Learning*, *Educational Objective*, *Materials*, *Procedure*, *Open-ended Investigation*, *Practicalities*, *Discussion Ideas*, *Extensions*, *Links to the Curriculum*, *Links to the Science Museum*, and *Links to Everyday Life*. This format was common to all teacher resources proposed by the Science Museum.

Key Learning and *Educational Objective* sections clearly stated what the students should learn from the activity. These sections described the overall educational goal of the experiment. Also, the sections explained how the experiment would teach students those key learning ideas and goals.

Open-ended Investigation provided teachers suggestions to make the experiment more open-ended, allowing students to think more independently. These suggestions provided the students with less direction to achieve their overall goal. This tied into one of the new goals of the UK science curriculum, to have students begin to investigate issues on their own.

The *Practicalities* section explained safety precautions for each experiment. The section described the importance of certain steps within each of the procedures to ensure that the experiment worked ideally. Lastly, it discussed possible replacement materials and the differences that they could make, and which particular materials have to be used for the experiment to work.

Discussion Ideas provided teachers with possible questions that would spark conversation within the classroom. These questions asked students about what went on during the experiment and why. The questions made students think about the experiment

in more detail about the science behind it. Also, with each discussion question, answers were provided to the teacher to help them understand the goal of each question.

Extensions was designed for teachers to use if they believed their students could go further with the experiments. The section provided ideas to extend the experiment to make it more educationally challenging for students, or to teach students on different topics. Many of the extensions also provided more discussion and scientific inquiry on the topic matter.

The three sections, *Links to Curriculum*, *Links to the Science Museum*, and *Links to Everyday Life*, were developed to show the teacher the relevance of what they are teaching in class. They also explain where in the Science Museum they can further investigate the topic, and how everyday people use the concept. The *Links to Everyday Life* was used to excite students about science, and showed them that many interesting professions need science on a daily basis.

The previous described guidelines were followed for each classroom prototype created. The resources developed for use in the museum had a separate set of guidelines.

5.1.2-Museum guidelines

The goal of the museum resources was to have students engaged with the Space and Flight Galleries and draw them to certain exhibits within those galleries. The guidelines to achieve the goal of the museum resources came from our observations of patterns and limitations of the Space and Flight Galleries. First, resources should focus on drawing the students into the galleries and having them interact with certain exhibits. The resources should also keep in mind the flow of traffic in each gallery and ensure that the school group does not obstruct other visitors. In addition, each individual gallery had its own set of limitations that allowed for a different experience depending on the space available, type of exhibits, and the overall congestion of the galleries.

The Space Gallery was located in the main artery on the ground floor. Therefore, it was one of the busiest galleries in the museum. However, one of its biggest advantages was its direct link to the UK curriculum. It was often filled with school groups who were either observing the exhibits in the gallery or just passing through. For these reasons, resources for use in the Space Gallery should not serve as an obstacle to the movement of

other visitors. The location of the Space Gallery made it inappropriate to use resources that force students to sit or stand in one place for an extended period of time. This constraint eliminated the possibility of developing certain hands-on activities to reinforce concepts in the gallery. Also, the educational resources needed to be quick so students are not in the gallery for long periods of time.

The Flight Gallery had a different set of requirements for the design of resources. The Flight Gallery had difficulty drawing visitors because of its location. It was located on the third floor, towards the back of the museum. The view of the gallery from the outside was obstructed on both sides. Unlike the Space Gallery, the Flight Gallery did not experience any problems with congestion. At most we observed only one or two school groups in the gallery at a time. Students did gravitate towards specific exhibits like the cockpit of an airplane, where they could walk into the cockpit. Due to the lack of traffic, designing resources that required students to stay in one place for an extended period of time was not an issue. Resources for use in the gallery were designed to make use of the full space provided in the Flight Gallery, which included a balcony that allowed visitors to come up close to the various aircrafts hanging from the ceiling. The configuration of the gallery allowed resources that could instruct students to spend as much time as required at individual exhibits. Hands-on activities could also demonstrate the concepts and principles of flight while comparing real-world objects in the same room that used the very same principles.

5.1.3- Flight Path Guidelines

The design guidelines for Flight Path, our online interactive game, were discussed with Frankie Roberto, one of the web developers working for the Science Museum. During this meeting, there were several points made on how to make Flight Path fit into the standards that were applied to the other games on the Science Museum's website.

The first point that was discussed was matching compatibilities with that of Launchball, one of the more popular games offered by the Science Museum (<http://www.sciencemuseum.org.uk/launchpad/launchball/>). Launchball was built on Adobe Flash[®], so the first requirement was that Flight Path had to be made with Adobe Flash[®]. Adobe Flash[®] is a developmental tool in order to make vector based animations. Unlike

an image taken from a digital camera that has little bits of colors known as pixels, vector images use math to create the image. If an image from a digital camera was enlarged several hundred times you would see these individual pixels, and notice the lack of detail. With vector graphics, they can be scaled to any size and still maintain its original quality. Flash is mostly used online for games, as it is very small in its compiled form, and can be played on a vast majority of computers since most computers have a flash player installed. To keep with the Science Museum's default template, Flight Path's width should be no greater than 800 pixels. As far as the programming language to be used in Flash, it was recommended to be Actionscript 2.0 as the older versions of Actionscript would be unable to provide some of the features needed in Flight Path, and the newer version of Actionscript would not be able to play on older versions of the Flash player such as 8.0.

When developing a scoring system it should be a summation of times per level, with unlimited lives and unlimited time to complete it. This would allow anyone to complete the game at their own pace, and would allow them to compete against their best time. Also, it would be helpful to use a ranking system, so if there was someone who received a very good time, they would be rewarded.

For more general guidelines, the interactive must not be too taxing on the museums' web server, so all processing power would be directed towards the client's computer. Flight Path also must not have any dynamically linking pictures or text. Dynamically linking in Flash allows pictures and text to be changed in Flight Path without having to change the project file. While this would be nice to have when updating information, if done it could potentially get lost and break the program. Instead the final game must all be compiled into one file and if changes were to be made, then they would be made from the project file. Also, because the museum used an HTML template to apply content on their website, adding any extra code to the template to provide certain features would not be ideal. In terms of bandwidth, there was no real limit as most schools have broadband, and as long as it did not take too much time to load, then it was acceptable.

There was no specific guideline as to what the frame rate for Flight Path must run at. Frame rate is how fast interactions in Flight Path are updated. To balance performance

with visual appeal, most of the museum's games ran at 30 frames per second. If the frame rate was slow (less than 30 frames per second), movement may appear jerky because the position of all the interactions were not updated as often. If the frame rate was too high (greater than 60 frames per second) then the viewers computer might have a hard time keeping up with all the interaction updating and thus slow down the computer. Also, the color theme of the interactive should match the galleries and it would be helpful to have a high color contrast for the visually impaired.

Content included should provide historical and scientific information in the form of pop-ups. The player should not be forced to read the information, disabling the continue button for a period of time, as players might have already read the information and just want to play the game again. In order to make this interactive productive as a classroom resource, teachers should have the ability to skip to a particular level that is covering what they are teaching for the day.

5.2- Classroom resources

In order for the classroom resources to be successful they needed to be hands-on and simple. The simplicity of the prototypes was not only for teachers but for students as well. The prototypes had to be simple for the students to construct, and display the educational objective in an obvious manner. For those reasons the following prototypes were developed: Balloon Rocket, Light Upon Earth's Rotation, and a Circus Activity. The Balloon Rocket and Light Upon Earth's Rotation were used to explain difficult topics in the area of Space such as Earth's rotation. The Circus Activity entailed three smaller activities, Cuddling Balloon, Airplane v. Bottle: The Similarities in Air Flow, and Paper Wing. Those three experiments demonstrated to students the main topics of flight, air pressure, lift, and air flow, and why an airplane wings has its particular shape. Also, a proposed resource of the Mars and Moon Lander was originally considered to be developed as a prototype, but due to time constraints it only went through the early stages of development.

5.2.1-Balloon Rocket

The Balloon Rocket was a Space-based activity that helped students learn about Space Explorations and Newton's Third Law of Motion. The Rocket Balloon was a team-based activity that used the idea of a race to motivate the students. Students had to have

Figure 7: Students setting-up Rocket Balloon



their Balloon Rocket, a balloon taped to a straw on a dental floss base course as shown in Figure 7, travel the furthest to win the competition. Before a final prototype could be proposed the activity was tested. The Balloon Rocket underwent three forms of testing: self-testing, student-testing, and teacher and staff

testing. From these tests a final prototype was designed in an attempt to incorporate all suggestions from testing.

The self-testing required thirty-two test-runs to inspect different possibilities and materials for the experiment (See Appendix T). During the self-testing it was determined that the length of the course needed to be at least seven meters long to allow students the ability to observe the distance traveled by the Balloon Rocket. Because the extension part of the straw bent during testing, that part of the straw cannot be used for the experiment. The testing also showed that the best material to use for the course was dental floss since it worked well and was cheaper and safer than the first proposed material, fishing line. We also considered using a clothes peg to hold and release the balloon, but after testing we found it easier for the person holding the balloon to just hold the balloon closed instead of using the clothes peg.

The main concern with the materials was which type of balloons should be used or if it mattered. The first type of balloons tested were round regular balloons, which worked but rotated around the dental floss. For that reason a pen was added to the bottom of the round balloon. The regular balloon did not flip over the dental floss with the weight at the bottom, and looked more like a rocket. The other balloon tested was a long balloon, which worked better than a regular balloon. The long balloon did not need any

weight added to the bottom of it and looked more like a rocket as well. The main flaw to the long balloons was that they were a lot harder to find than regular balloons. Since both balloons have pros and cons, it was concluded that either balloon could be used for the experiment.

Another part of self-testing was to try out the proposed extensions of the experiment. One of those extensions placed a paper cup on the nose of the balloon to show the use of other objects in space exploration. After testing it multiple ways we decided it was not effective and it should not be part of the final design. The other proposed extension was to position two Balloon Rockets to collide head on in the middle of the course. This method was hard to replicate, with each attempt providing different results. Therefore, the extension would be more about showing what happened during different types of collisions followed by a discussion on what occurred with each separate collision, and would not focus on the balloons colliding perfectly in the middle.

After the completion of the self-testing, student testing was conducted. The Balloon Rocket was tested with the proposed changes with a science club consisting of Year 7 students at the Bridge

Academy. The students were given a modified version of the procedure (See Appendix S) and all materials were at their station. Once the initial direction and explanation of the experiment were given, students began constructing the Balloon Rocket. In a matter of five minutes all but one group had already shot off one of their rockets, as shown in Figure 8.



Figure 8: Students Racing the Balloon Rocket

This demonstrated the ease of assembling the experiment and the clarity of the procedure. One group did experience difficulties due the end of dental floss, which became rough near the end of the roll. An addition to the *Practicalities* section was made to warn about not using the end of the dental floss roll.

During the student testing, a race between groups was proposed and students had to figure out how to make their balloon travel the furthest along the course. Right away,

students began to slope the course at a downward angle making it easier for the Balloon Rocket to travel the full length of the course. This was an idea we did not think of or propose to the students, which showed the students' ability to think scientifically during an open-ended experiment. Next, the students were asked how they could stop the round balloon from spinning around the dental floss. The first answer given was by a girl who said that they must add a weight to the bottom of the balloon. Students' knowledge for this experiment was observed when one student asked why dental floss was used and another student answered by saying that it provides less friction than something like string or wool, allowing the balloon to travel further on the course.

We experienced difficulties during the proposed extension where the balloons collided. Students were unable to replicate this on a common basis due to the clamp stands used as the ends of the course causing the dental floss to not be pulled tight at all times. When the floss was not pulled tight a valley occurred in the middle and the Balloon Rockets did not travel as far. This issue was emphasized in the practicalities sections of the final prototype.

Although the students were engaged with the activity for a long period of time, after about forty-five minutes of racing and attempting the extension for the Balloon Rocket, their focus started to fade and they began to design their own balloons. At this point the experiment came to an end and a discussion started. The students were asked why the balloon shot down the course, and the first student to respond explained that the air came out and pushed it down the course. The students knew the idea, but did not know it was Newton's Third Law, which states that for every action there is an equal and opposite reaction. This was the main educational goal of the project. Therefore, we explained to the students the concept of Newton's Third Law, and repeated how it played a role in the Balloon Rocket. They were then able to relate Newton's Third Law to space explorations and shuttle launch. Students described the forces that affect Space Shuttles during launch as gravity and air resistance. With some prompting, students were able to state that a Space Shuttle must overcome the atmosphere during a launch as well. The students in Key Stage 3 proved to be very capable of understanding the educational points behind the experiment, and why this experiment was designed.

After the educational discussion, we asked the students for suggestions for our prototype. Many students wanted to see accessories for the balloon, such as feathers. Students did not enjoy having to tape the pen to the bottom of the balloon, and enjoyed the long balloon concept much better. They also did not enjoy having to re-set up the balloon after every launch. Students wanted to test balloons of different size and shape, and what would happen with things placed inside the balloon. Another idea by a student was a relay race with Balloon Rockets stationed at different position on the course. Lastly, one student wanted to see the effect of using different gases besides air. All these suggestions were considered, and some were further implemented into the final design of the prototype.

At the end of the testing and discussion the teacher commented that students from all ranges of capabilities enjoyed and were engaged with the experiment. For that reason, the teacher believed that the resource was an effective and overall good resource.

The Balloon Rocket was next tested with teachers and staff, and the idea of a race was also proposed to the two teams. The two teams instantly grew competitive and began to test-run different options for their final design. The groups tried using two balloons set-up on the straw many times. Each time the Balloon Rocket did not travel farther than when it was tested with one balloon. Also, after a few test-runs and some ideas from us, the teams started to slope their course.

The testing of Balloon Rocket with the teachers and staff provided us with some good ideas for the experiment. First, the concept of a race between Balloon Rockets should be included in the procedure for the prototype. The addition of a competition made the experiment more engaging. Second, for ideal construction of the Balloon Rocket, only one balloon should be used. Third, was the idea of setting up the course above the classroom. For example, the Balloon Rocket could travel from the top of the interactive whiteboard to the other end of the classroom. This would allow all students to observe the Balloon Rocket in action, and it would also be enjoyable and fun for the class.

From the results of the testing, a final prototype design with teacher notes was constructed (See Appendix D). The Rocket Balloon had a clear link to the UK curriculum pertaining to units on Forces and Solar System and Beyond. If teachers choose to have

their students calculate the average distance traveled, it would also link to the math section of the curriculum. A trip to the Science Museums' Space Gallery, Launchpad Rocket Show, or the IMAX Space Show would also provide the class further studying in the areas of Forces and Solar System and Beyond.

The final design included clear sections on the educational objective and key learning of the prototype. The educational objective of the Rocket Balloon was for students to understand the concept of Newton's Third Law and how it related to Space Exploration. This was observed in this experiment during the release of air from the balloon and the reaction came from the balloon shooting down the line. Students then could draw the connection to a Space Shuttle launch and that Newton's Third Law was why it released so much energy in the form of fuel.

5.2.2- Light Upon Earth's Rotation

The importance of the Earth's Rotation was the main educational goal of this activity, which was a more discussion based activity for use in the area of Space. It entailed placing an inflatable spherical object in the middle of the room representing the Earth and attaching a figurine onto it. The lights were then turned off and a flashlight, which represented the Sun, was used to shine light onto the spherical object. The Earth was then rotated and the figurine was observed to show the importance of the Earth's rotation and its links to night and day and the length of a day. This prototype underwent self-testing along with teacher and staff-testing before a final design was proposed.

The self-testing required detailed test-runs (See Appendix X) that provided us with changes and ideas to improve the prototype. Testing provided changes to the materials, the first was the regulation of the size of the figurines since bigger figurines did not stay attached to the Earth. We determined the figurines had to be small, about four to five centimeters in length and cannot weigh over one pound. In addition, the sphere-shaped object had to be approximately 90 centimeters in circumference. Also, the distance between the person holding the sphere-shaped object and the person with the flashlight should be no more than two and a half meters; otherwise the clear split between night and day on the sphere would not be observed.

Self-testing also provided changes to the procedure of the prototype. It was much easier to hold the spherical object than to hang it. Not only was it difficult to find something to hang it from but not every sphere-shaped object would have a place to thread string through. The procedure also was changed to attach the figurines before performing the experiment. This was changed to ensure that figurines were placed on the sphere securely. For this reason a recommendation was added to wrap the blu-tac around the bottom of the figurine, which allowed it to stay on the globe better.

The extension was self-tested by placing three corks on the same meridian of the sphere-shaped object. The object was then rotated in an attempt to observe shadows for each cork. Many issues came up with this extension. The corks weighed down one side of the sphere-shaped object, tilting the object slightly, and the shadows were only visible at one certain time. The extensions did not work effectively and was disregarded as part of the prototype.

After evaluating the experiment through the self-testing, we did not find this experiment to be stimulating. We felt that if we did not find it exciting that it would be unlikely that students would enjoy it either, especially since it was a discussion based experiment. Also, it was extremely frustrating putting the animals on the sphere-shaped object, and we believed teachers would not enjoy having to place each animal on the sphere-shaped object. Not all the materials in the proposed prototype were easy or cheap materials, which was one of the main points expressed by teachers. Lastly, if the prototype did not involve much participation from students the teachers would have to lead the students in the discussion.

The prototype was discussed at the teacher and staff testing session, where recommendations for improvement of the proposed design were asked for. The group discussed possible experiments, but none that were relevant to the already proposed prototype. The suggestions provided were mainly focused on the Earth's tilt and its effects on seasons, which was not the goal of our original prototype to explain the importance of Earth's rotation. Although, many of the ideas were good ideas due to the time constraints of the project they could not be implemented. The prototype did not fit the criteria of the classroom resources of being hands-on and using simple materials. For this reason, the prototype of Light Upon Earth's Rotation was dropped from our final design.

prototypes, but the teacher notes were still constructed for the activity (See Appendix EE).

Although the design was dropped from our final designed prototypes, we do recommend some of the suggestions proposed in the testing session be developed. These suggestions were basic ideas and focused more on teaching the concepts of Earth's tilt and its relation to the seasons. The first idea was creating a paper mache Earth and having students spray paint, which represents the sunlight, onto it when it is tilted. This will show students that when the Earth is tilted certain areas get direct sunlight and others do not, providing an option to discuss that the direct sunlight occurs in summer and where there is indirect sunlight in winter. The second was the idea of using solar paper on a spherical object representing the Earth. The Earth would be tilted and a flashlight would be used to represent the Sun. When the flashlight hits the solar paper, more direct light would cause a change in color of the solar paper. The area observing more direct light would have a more severe change in color, and the areas with indirect light would have a subtle change in solar paper. Once again students could use these results to explain the concept of seasons. These ideas were very basic concepts that would need to go through the whole developing process and testing phases, but we believe that they could be effective resources for teaching what one teacher believed was the most difficult concept to teach to students.

5.2.3-Circus Activity

Through three small experiments, students drew the connection as to why an airplane wing had a certain shape, and how that would help the airplane achieve flight. The three experiments were all simple and quick experiments that could be used individually to explain one topic, or as a group to explain the overall objective to show the importance of the shape of an airplane wing. The three experiments were individually tested by the team, the teachers, and the Science Museum Staff before a final design was created for the activity.

5.2.3.1-Testing of Cuddling Balloons

The Cuddling Balloons experiment had two balloons hanging from a coat hanger at even length and no more than five centimeters apart. The goal of this experiment was to get the two balloons to touch together by blowing air somewhere on or around the balloons, to show the effects of a difference in air pressure. The concept of Cuddling Balloons was first proposed with two separate options of using balloons or using toilet paper rolls. After testing the toilet paper rolls method (See Appendix Y), it was disregarded due to its difficulty and failure to work. The final prototype only entailed the use of the balloon method as shown in Figure 9.



Figure 9: Set-up of Cuddling Balloons

The Cuddling Balloon method was thoroughly tested (See Appendix Z), and changes were made by the results of the testing. The requirements for the materials and procedure were found during the testing of Cuddling Balloons. The balloons needed to be around five centimeters apart from each other, because anything further apart would not produce the results of the balloons touching. If they were too close, the results did not seem counter-intuitive. The balloons also needed to be the same distance down the hanger, approximately twenty to thirty centimeters. The balloon size also had to be regulated to around forty-five centimeters in circumference. The testing showed that the balloon needed to be filled with water; therefore, a deflated balloon should be completely filled with water before it is inflated.

The testing of the materials showed that the results were not altered with different types of string or hangers. A practicality was added to address that it was a lot easier to use a wire hanger to tie the balloons than a plastic hanger. Also, it was added that the balloons should be balanced after each attempt. This ensured that the balloons were

touching in the middle due to the change of air pressure and not because the balloons were unsteady.

The extension of attempting to get four balloons to touch in the middle was tested, and after attempting all of our possible strategies we were unable to successfully achieve the extension. The extension would stay for the final prototype design because it encouraged students towards scientific investigation and inquiry. Also, it is very possible that students could come up with a method to complete this extension that we did not think of, which would be an impressive achievement.

After the testing, an open-ended investigation was proposed. Students could be challenged to have the balloons touch in the middle, but would not be told where to actually blow for that to occur. The group with the smallest balloons, largest distance between the balloons, and least amount time would win the challenge.

Teacher testing occurred with the Cuddling Balloons, and we asked the members where they should blow on the balloons to get them to touch in the middle. Immediately, the members tried to blow on the side of the balloons, and soon realized they had to blow in the middle of the balloons. This showed us that this experiment will provoke scientific thought no matter what age. The main comments made about the Cuddling Balloons were that it was mostly a demonstration and not a hands-on activity for the students. Also, they recommended that the discussions needed to be based more on the difference in air pressure then stating that outside the balloons was high air pressure and in between the balloons was low pressure.

5.2.3.2- Testing of Airplane v. Bottle: The Similarities in Air Flow

The Airplane v. Bottle:
The Similarities in Air Flow was an experiment to show the movement of airflow around circular objects. A bottle is placed in front of a piece of paper that was shaped as a wing's flap and taped to the

Figure 10: Set-up of Air v. Bottle: Similiarities in Air Flow



table, which is shown in Figure 10. The students then blow air into the bottle and watch the paper flap flutter from the air traveling around the bottle.

The Airplane v. Bottle: the Similarities in Air Flow was first self-tested to make requirements for the materials and procedure and to ensure it worked and displayed the goal of the activity, which was to show that air flows around circular objects (See Appendix W). The regulations and guidelines for the experiment that were first tested was the distance between the bottle and paper. It showed that the distance between the bottle and paper should be around ten centimeters. The other regulation was the size of the paper, which was ideal at ten centimeters long and two-half centimeters wide. If the paper is not around those regulations the paper does not flutter as well. The circular bottle also needs to be between the size of 500mL and 2L.

During testing, the bottle did not always stay in place, thus a practicality was added so that the bottle should be filled with a quarter of water to maintain stability. Lastly, extensions were added for the prototype. The first extension was to try using a straw to blow onto the bottle and observe the results. This showed that even with direct air flow on the middle of the bottle, the air still traveled around the bottle to flutter the paper. The next extension discussed the concept of blowing air harder or softer on the bottle and the effect it had on air flow. Lastly, an extension was created to show the effects of air flow when changing the distance between the bottle and paper flap. All these extensions were created because they were common things that could be changed during testing that built upon the knowledge of air flow during the experiment.

During the teacher and staff testing session, the members were amazed at how far you could be away from the bottle and still have the piece of paper flutter behind the bottle. Overall, the experiment was thoroughly enjoyed by the members, but there were suggestions proposed. One suggestion was to make the paper flutter smaller in width to be able to better demonstrate the movement of air and where it ends up after traveling around the bottle. The members of the group appreciated our extension templates, which asked students to draw the air flow they observed around the bottle, as well as around an airplane wing from what they learned in the experiment (See Appendix G).

5.2.3.3- Testing of Paper Wing

The paper wing was used to teach students about the effects of a change in air pressure and how it provided lift. The paper wing represented the shape of an airplane wing and how, without that shape, lift would not be observed. When testing the Paper Wing experiment, we conducted nine test-runs (See Appendix U). Through our test-runs, we determined that holding the flat base of the paper worked very well to accurately demonstrate that lift acts on an airplane's wing. When having the oval shape of the plane's wing facing you rather than away the paper wing did not generate lift. When conducting this test-run, the wing generated no lift and the experiment failed. As for using different materials, copy paper worked best for this experiment, not only because of its make-up, but that it was also affordable and very easy to obtain. We tried using thicker paper, such as construction paper, to conduct the experiment, but it was not as effective as the copy paper, thus solidifying our choice for using that material.

In terms of the Paper Wing prototype template, we determined that folding the copy paper in half without forming a crease in the middle was an important practicality. We also ensured that when conducting the experiment, one should place his or her bottom lip just above the taped ends of the paper for proper air to be blown onto the paper wing. For an open-ended investigation, we felt that asking students to determine an appropriate way for placing the paper wing to generate lift would be great for helping them understand the concept of differences in air pressure.

The Paper Wing was tested with the teachers and staff as well. The members of the testing found the simplicity to be good, but it was a little hard to observe the concept of lift. One member of the group proposed a new version of the Paper Wing, which involved taking the Paper Wing and putting a straw through the middle of it and threading string through the straw. The member then demonstrated that if you spin around while holding onto the ends of the string, the paper wing part would be lifted to the top of the string. This form of the paper wing demonstrated the concept of lift in a much easier way than the previously designed prototype. The concept presented was implemented as our final prototype, and the name was changed to Paper Flyer, as shown in Figure 11.



Figure 11: Set-up of Paper Flyer

The Paper Flyer then underwent self-testing (See Appendix V). During self-testing, it was discovered that tying a knot at the bottom of the string allowed the Paper Flyer to stay attached to the string when it was not being held with two hands; the change was then added to the procedure. After the self-testing, two extensions were added to the experiment. The first involved flipping the Paper Flyer upside down and observing if lift still occurred, and the second involved spinning in the opposite direction and observing if lift still occurred.

5.2.3.4-Final Design of the Circus Activity

From the testing of the three individual activities, the final design of the Circus Activity was developed (See Appendix E-H). The Links to the Curriculum for this activity as a whole were the topics of Forces, and Pressure and its Moments. As for The Cuddling Balloon experiment, a link to the curriculum for weather was provided as well to discuss the changes of air pressure and the effects it has on weather. The Links to the Science Museum for the Circus Activity were the Flight Gallery and the Feel the Force show in the theatre.

The overall educational objective of the circus activity was to be able to understand the shape of an airplane wing. Each smaller activity had its own educational objective as well. The Cuddling Balloon experiment was used to display the effects of air pressure on objects, and that objects would move when there was a change in air pressure. The Airplane v. Bottle: The Similarities in Air Flow experiment had a goal to teach students about the need for circular objects for flight, and how air traveled around those objects. Lastly, the Paper Flyer experiment aimed to show that a change in air pressure can cause objects to be lifted off the ground depending on their shape.

5.2.4-Mars or Moon Lander

The Mars and Moon Lander was a resource that was originally proposed to be developed by the team. The resource was not further developed than the basic concept due to time constraints. The educational goal of the resource was to teach students about Space Exploration and the force of gravity. The objective was to create a Mars or Moon Lander that could successfully hold a clay figure intact during a hypothetical landing onto Mars or the Moon. The activity would be an open-ended group project, where groups would be proposed the idea and given a budget to construct the Lander. The groups would then have to choose the important materials to use for construction of the Lander. After the students constructed the Lander it would be dropped from an appropriate location, and it would be observed if the clay figure was still intact. A successful landing would be one where the clay figurine was not damaged and still remained in the Lander. We believe this would be a useful resource for the classroom since it links to Space and Forces, and is also a very hands-on and investigation based activity.

5.3-Museum Resources

The goal proposed for the museum resources was to have students interact and engage with exhibits within the Space and Flight Galleries. The proposed resources needed to be quick to accomplish but be enjoyable for students as well. Therefore, the resource prototypes for use in the Science Museum that were developed were a Scavenger Hunt and Advertising Campaigns. Both the Scavenger Hunt and the Advertising Campaign have separate worksheets specific to either the Space or Flight Gallery. A hands-on activity was also created mainly for use in the Flight Gallery, Spinners.

5.3.1-Spinners

The Spinners was an activity that involved students constructing spinners out of paper, dropping them to observe how they rotate. The basic design of the Spinners is displayed in Figure 12. It was designed to teach students about the principles of flight mainly focusing on air resistance. Spinners can be used either in the classroom or in the Science Museum, but the activity was recommended for use in the museum to promote hands-on activities within the Flight Gallery. We tested the Spinners activity on the

observation deck in the Flight Gallery. There were a total of 23 test-runs. (See Appendix AA) The first test-run used a wide template in which a single piece of paper made a single spinner. This design was a failure as it was too wide to spin properly. We switched to a design where the template contained two identical spinners per page instead of one. (See Appendix K) The thinner design of the spinner not only worked better, but less paper had to be used for construction of the activity.

The Spinner was first tested under poor conditions by tearing the template into the final design. The poor design worked and showed that even with a poorly folded and torn template the Spinner still worked



Figure 13: Set-up of Spinners

successfully. By identifying that folding and tearing the template worked we eliminated the requirement for scissors as it would be a hassle for teachers to bring scissors to the gallery. Although, it worked when poorly folded we found the design worked best when folded neatly as detailed in the practicalities.

We then did a variety of tests that could be used for extensions. First, we changed the length of the flaps and shape of the template, and this did not affect the results. Due to testing we added the extension of how weight and the position of weights affected the spinner along with an extension for changing the shape of the flaps. We then tested the affect of rolling the base. We saw that it still worked, except the Spinner landed upright; therefore, we made it into an extension. We then tried throwing the spinner in the air to see what would happen and saw that the spinners righted themselves and fluttered back down as they have normally done. Upon seeing this happen we added this as our third extension.

During the teacher and staff testing, the spinner was found to be an enjoyable activity. They had no trouble following the procedure and were able to start dropping them in minutes. The teachers and staff successfully folded, added paper clips, and began to change the shape of the spinner by tearing off pieces. They were able to see that the spinner would not spin if too much weight was added or if the base was shorter than the

blades. When trying out the extension where they rolled up the base, we witnessed confusion as some tried to tightly roll the base. We recommended images be created for all extensions to help teachers and students understand what they were supposed to achieve. There were also some suggestions in response to the use in the museum. Understandably, they were concerned that the spinners would fall into the exhibits; we decided to include the location of a designated area away from the exhibits in the teacher templates.

Using the results from our testing we developed the final template for the Spinners activity (See Appendix I). The Spinner was targeted towards the Flight Gallery and was the only developed prototype that could either be used in the museum or in the classroom. It linked to the curriculum through a demonstration of forces, specifically air resistance. For the Link to the Curriculum section of teacher's notes we connected it to the subject of Forces, specifically air resistance that are covered in the UK science curriculum.

The Key Learning of the activity demonstrated how air resistance plays a part in flight. As the spinner fell down the air pushed up against the flaps and was forced to the side, creating the spinning motion the students observed. In addition to the twirling motion the air resistance also acted in opposition to gravity, slowing the spinner's descent to the ground. The educational objective of the guideline was for students to understand the effect of air resistance on the objects and how it varied based upon weight, shape, and initial speed.

5.3.2-Scavenger Hunt

Another dynamic worksheet used to draw students to many important artifacts was by challenging them to complete a Scavenger Hunt within the Space or Flight Galleries. The set-up of the Scavenger Hunt included drawings and questions, similar to the format of the worksheet by the Imperial War Museum (See Appendix N). We obtained the Imperial War Museum worksheet from the Imperial War Museum website (Large Exhibits Gallery: First World War Key Stage 3, n.d.). The only difference from the Imperial War Museum worksheet was that the drawings would consist of incomplete pictures of objects, where only half of the actual picture was given, an example is shown

in Figure 14. The objects for the drawings we selected were located in either the Space or Flight Gallery. For the Space Gallery objects, we selected the Apollo Lunar Lander, the Top Sat Satellite, the Saturn Rocket, and the Beagle. As for the Flight Objects, we selected the Wheel and Tyre of the Beardmore Inflexible, the Gloster E. 28/39, the Vickers Vinny, and the Wright Brothers Plane. We chose these drawings because most of them involved historical points in time that highlighted accomplishments never before achieved. Having students exposed to this historical importance is a great way to engage students in the topics of Space and flight. These drawings would then be given to the students on their Scavenger Hunt, where they would locate the pictures and finish the drawings (See Appendix L and M). In addition to the drawings, the Scavenger Hunt would entail a few

Figure 15: Example of Scavenger Hunt

questions in regards to each drawing. These questions invoked discussion of the objects drawn and give the students some thought about the purpose and significance of each one.



The idea of using half completed pictures came from the anti-coloring book concept that was discovered from our visit to the Tate Modern. The Tate Modern was known for its in-depth and creative teacher resources, but after a visit there it was realized that some of these resources were unrealistic for use by the Science Museum. From our observations, students who visited Tate Modern were engaged through their class guided tours provided by Tate Modern, but the amount of students who visited Tate Modern were nowhere near the large amount of students who visited the Science Museum in London. We came to the conclusion that creating a template based off of this resource would be a great way to not only minimize the space needed to gather students in the Science Museum, but also to provide active learning within the Science Museum's Galleries.

We then took the time to interview the Space and Flight curators from the Science Museum. After listening to their thoughts and suggestions, it became clear to us that the Scavenger Hunt had to be developed so that it was a more personal experience for students. For example, instead of just having students answer questions relating to the objects in the gallery, we would incorporate questions that would ask students about their opinions of the subject matter. In regards to a question asking students about what type of engine an airplane had, asking them a question about what it would be like to be a pilot may stimulate the students' interest in the subject matter. Having personal questions like these will engage students in the topics of Space and flight. As for Space, the Space curator said how mentioning the European Space Agency may also attract students to the Scavenger Hunt because it relates to something closer to home for them. We originally had a storyline for the Scavenger Hunt that involved NASA, but after speaking to the Space curator, having the European Space Agency would better suit the students and their understanding that the UK also is involved in Space.

The teacher and Science Museum Staff tested our idea of the Scavenger Hunt, and many suggestions and recommendations were given. The most important recommendations that we implemented into our Scavenger Hunt from the teachers and staff were more dynamic questions, students to be attracted to more than four exhibits, and the use of less text and more pictures. One teacher pointed out that if her students were to answer some of the questions, they would simply put one word answers such as "yes" or "no". Asking more thorough questions that required the students to think were better suited. As for the choices of exhibits, the teachers and Science Museum Staff were pleased; however they wanted students to experience more of the Space and Flight Gallery rather than just four exhibits from each. Having more objects mentioned in the Scavenger Hunt would help give the student a more detailed visit to the Space and Flight Galleries. They also suggested mixing and matching the order in which the students were to find the objects so as to avoid congestion at each object's location. As for the pictures and text, the teachers and Science Museum Staff felt that more pictures would be suitable for students than text. Having more pictures would engage the students more with the two galleries and avoid instances where they were bored.

The Scavenger Hunt would be structured to Key Stage 2 students, primarily because we felt that Key Stage 3 students would not enjoy the concept of a Scavenger Hunt, thus not being able to fully take advantage of the educational aspect of the activity. Key Stage 2 however would enjoy the simplicity of the Scavenger Hunt. They would have the opportunity to explore the two galleries in a manner they enjoyed, drawing pictures and answering questions that relate to the descriptions found at each objects' location.

5.3.3-Advertising Campaign

The Advertising Campaign asked students to pick an object in the gallery and write an Advertising Campaign to convince the “consumer” to go to visit a certain exhibit in the Space or Flight Gallery. The resource was primarily targeted at students in Key Stage 3, with slight alterations in the instructions directed towards each gallery. The Advertising Campaign was created in conjunction with the Newspaper Article resource. Both activities were similar in their overall concept, except the Advertising Campaign was more open ended, with no guidelines for where text or a picture were located, which forced the students to decide what would be appropriate to sell from the gallery. The resource's underlying purpose was to get students to tell others why the exhibits they saw in the galleries were important or their favorite exhibit. Instead of just observing the exhibits in the gallery, they had to understand and identify the exhibits' relevance in order to draft their campaign.

Alterations were also made after meeting with the Space Gallery curator. She explained that the European Space Agency was recruiting astronauts. We then changed the space Advertising Campaign to act as a recruitment tool for the European Space Agency. This would provide a direct link to something currently going on within the UK culture that is directly linked to the topic of Space.

The Advertising Campaign received a positive response from the teacher and staff testing. They liked how it brought students to the exhibits and how it could be used for before as a pre-lesson for the museum visit, during, and after a trip to the museum. The testing also made us aware that the activity tied into Design and Technology component of the curriculum, which we did not know existed. This was encouraging as the UK

curriculum strongly recommended cross curricular activities. We also observed how some members of the group held the template upside down from the way we originally envisioned it. During the design of the template we were concerned that the boxes and shapes would be too restrictive. This showed that the template was loose enough to allow different perspectives on how to approach it.

The Newspaper Article was targeted at students in Key Stages 2 and 3, with variations in titles and wording according to the gallery they are used for. It instructed students to write a few short articles on the exhibits and draw a few pictures depicting the objects in the gallery. It operated on the same principles as the Advertising Campaign. While the Advertising Campaign was made to be open-ended, the Newspaper Article was built around structure. The template had lines for where text was supposed to go and boxes for pictures.

During the teacher and staff testing of the Newspaper Article, we found that they had difficulty figuring out where to start. The template appeared too vague and daunting for them. They suggested that we delete the sidebar or include a date to clarify what this day in history actually was. In addition, they also thought it would have been helpful if we included a picture or short description to help spark their imagination. While their suggestions were helpful, it led away from the exhibits in the museum and more on the broad topics of Space and flight, which was not our focus. We ultimately decided to include an important date on each template and a quote that stated that the article the student wrote referred to the best exhibit in the Space or Flight Gallery. There were also comments on simplifying language, by using more appropriate vocabulary for Key Stage 2 and including a byline in the paper, both of which we complied with.

Both of the final designs for the Advertising Campaign and Newspaper Article followed the same basic setup (See Appendix O-R). First, they contained scenario where either a hypothetical graphic designer or journalist was disabled and the student must take their place and finish the advertisement or article. The second part of the design included the template for the students to fill out by drawing and writing about what they saw in the galleries. Through the utilization of either resource students would gain a better understanding of the exhibits in the gallery.

5.4-Flight Path

The design of Flight Path, the online flight interactive game we created and developed, was an educational online game that would be used for classroom resources, offering historical and scientific topics covered in their curriculum based on flight. Flight Path consisted of ten levels, each with varying difficulty and different historical and scientific contexts. This content was offered in the form of informational pop-ups before the start of the level and after completing the level. Students playing the game have the ability to change various values that would affect the flight of the game such as the angle of throw, power of throw, and degree of elevators in order to guide the plane to hit the targets. Changing the elevators in Flight Path, affected the way the plane rises and falls or make loops. As the levels progressed throughout the game, the objectives to complete the level became more difficult, thus making the students change the values to throw the plane accordingly.

The game was scored by a cumulative timer with an unlimited amount of tries. At the end of completing the game, each level's time was added up and output a total time that players can improve on. Rather than restricting time to complete game, or a restricting the number of lives, this method enabled students to play at their pace, without feeling pressed for time.

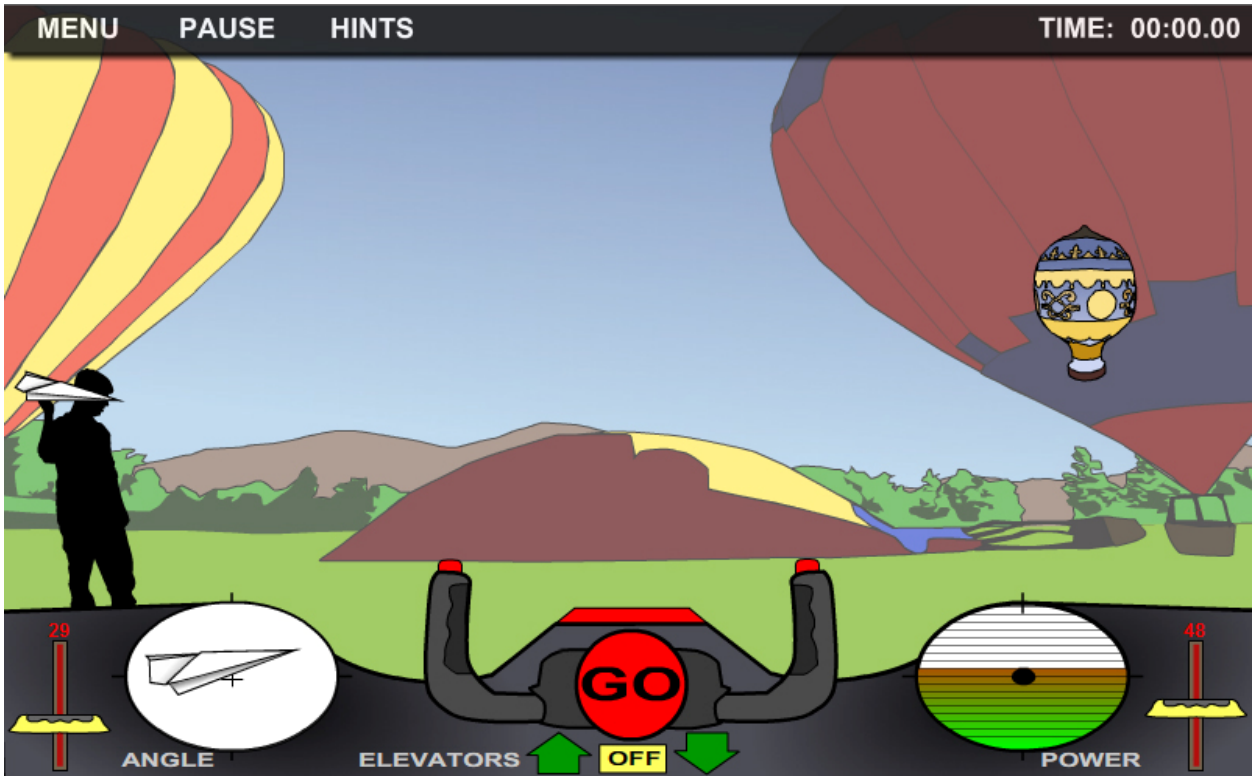
The look of the interface was designed to look like the interior of a plane cockpit, and the backgrounds of each level were vectorized versions of pictures that represented the theme of flight. Figure 15 displays the interface of Flight Path, and Appendix DD shows all the different backgrounds. The game could be paused at any time, which stops the level timer allowing the viewer to take a break. For educational purposes, levels could be skipped in order to go to levels that have educational importance for that day's discussion in class. This would consist of a teacher inputting a code before the game starts, instead of the beginning at the first level. These level codes would be displayed at the beginning of each level.

We also made adjustments to the game after meeting with the Disability Audience Coordinator. She overlooked the game and made several suggestions. When the pop-ups appeared on the screen, it would be difficult for the visually impaired to determine where they should focus. Through discussion we implemented a solution where we darkened the

controls and background while the pop-up was on screen. We also showed the coordinator the various backgrounds for Flight Path. She commented on a few of them being too dark or that others were hard to determine what they were supposed to be. The use of thick outlines was also emphasized to make it easier for the visually impaired to make separations between different objects. Generally, she stated that it should be easy to determine what was part of the foreground, and anything that is in the background should not be mistaken for an object that is active. We achieved this by brightening the background so it would be easier to identify the paper plane, obstacles, and target.

After the basic design of the game was created Flight Path was tested with teachers and museum staff. Based on that testing, we learned several key points to further enhance the flight interactive. First, was making sure that the paper airplane interaction does not interfere with the background picture. We solved this by fading the background of each level a little, so the player could better differentiate between the two. Next, was to split the history and science facts since students may see all this text and want to just click through. We fixed this by having more than one page that broke up the facts with lots of interactive animation examples. Finally, would be to make sure the instructions are very clear. This was so that there was no question on how to play the game. Even if it seemed intuitive, it should still have instructions to make sure that no one playing has any misunderstanding as to what was going on.

Figure 16: Screen Shot of Flight Path



6.0- Conclusions and Recommendations

The goal of this project was to develop teacher resources for Key Stages 2 and 3 teachers on the topics of Space and flight. In order to accomplish this goal we conducted research on the teachers' wants and needs for resources, students' engagement in science, and current use and design of resources. From this research we were then able to develop guidelines for classroom, museum, and online resources. When developing resources we believe that the Science Museum should ensure that all resources fulfill the needs of teachers, engage students, and follow the guidelines we proposed. Following the guidelines we developed resources for use in the classroom and museum; we developed the following educational resource prototypes Balloon Rocket, Circus Activity, Scavenger Hunt, Advertising Campaign, and an online flight interactive game, Flight Path. After the development of the resources we proposed recommendations to improve our designed prototypes and general recommendations to the Science Museum in London.

6.1- Teacher Resources and Guidelines

From our interviews with teachers and staff members along with past research we determined that teachers use resources which have:

- clear curriculum links
- easy to use
- little preparation time
- engages students.

During teacher interviews we also asked about what type of resources were most effective and enjoyable for their students. Most teachers responded that hands-on and interactive resources are most enjoyed by their students. We also analyzed in these interviews if there was a considerable difference in gender or culture for students engagement. The teachers responded that they did not see a considerable difference in gender, and only one response for culture discussed the topic of language barrier. For this reason we did not attempt to develop different resources for different genders, but we did attempt to create resources that would be enjoyed and directed towards both genders and all cultures. For example, in our online flight interactive game we made sure that the

character could be either male or female. We took this information and developed design guidelines for the resources we developed. These guidelines varied depending on what the goal and use of the resource was.

The guidelines of the classroom resources were that they had to be easy to use and prepare, have a clear link to the curriculum, and be hands-on activities. For this reason detailed teacher notes were made for the classroom resources. These guidelines provided assistance for the teachers in their preparation for the activity. The notes entailed sections on *Educational Objective, Key Learning, Materials, Procedure, Practicalities, Open-ended Investigations, Discussion Ideas, Extensions, Links to the Curriculum, Links to the Science Museum, and Links to Everyday Life*. These sections provide teachers the main goal of the activity, a more open-ended investigation, relevant discussion topics, extensions for various difficulties and topics, and its links to topics covered in both the classroom and the Science Museum.

The museum resource guidelines, however, were more specific to the certain gallery they were intended to be used for. The resources were also designed to be easy to use and print off for teachers. Through our observations we discovered that the Space Gallery was a traffic-heavy gallery in the center of the museum, while the Flight Gallery was less congested, located on the third floor. Therefore, the resources developed for the Space Gallery needed to be quick, and could not entail discussions within the gallery. The resources created for the Flight Gallery could be more open-ended, allowing the students to interact with exhibits and have a set discussion within the Flight Gallery.

6.2- Designed Prototype Resources for Space and Flight

The following resources were proposed for Space and flight:

- **Balloon Rocket**
- **Circus Activity**
- **Spinners**
- **Scavenger Hunt**
- **Advertising Campaign and Newspaper Article**
- **Flight Path**

All these resources underwent some form of testing: self, student, or teacher and staff testing. The Balloon Rocket and Circus Activity were developed for use in the classroom to cover the topics of Space and flight respectively. The Scavenger Hunt, Advertising Campaign, and Newspaper Article were created for use in the museum to draw students to exhibits within the Space or Flight Gallery. The Spinners activity was developed with the guidelines of a classroom resource, but due to the open space in the Flight Gallery it was recommended for use in the museum. Flight Path was developed to be used on interactive whiteboards in the classroom, but it can also be used wherever there is an internet connection.

The two resources for classroom use were developed to provide students with hands-on opportunities, and teachers the ability to teach their students about difficult topics in Space and flight. The Balloon Rocket focused on teaching students about Space Exploration and Newton's Third Law, where every action has an opposite and equal reaction. This activity was a group based experiment and the idea of making it a race was used. The Circus Activity entailed three smaller experiments to teach students about the importance of a wing shape for flight. The three smaller experiments, Cuddling Balloons, Airplane v. Bottles: Similarities in Air Flow, and Paper Flyer, can also be used individually to teach about the concepts of air pressure, air flow, and lift respectively. The testing sessions showed us that both activities were thoroughly enjoyed by all members. We also received suggestions to approve these experiments, such as adding on a relay race concept for the Rocket Balloon. The most significant suggestion we received during the teacher and staff testing was a new design for the Circus Activity. The idea was to change the original idea of Paper Wing to the Paper Flyer, which taught the concept of lift more effectively.

Spinners was an activity used to teach the concept of air resistance, and its effects on flight. The Spinner was constructed simply out of a paper template and a paper clip. The activity was recommended for use in the Flight Gallery to provide a hands-on experience within the gallery. During the testing sessions everyone found the activity enjoyable, but believed it could use clarity in the written procedure. For that reason we designed a picture based procedure for the Spinners activity.

The museum resources of Scavenger Hunt, Advertising Campaign, and Newspaper Article were developed to have students interact with Space and Flight Galleries. These resources each were specific to a certain age group. The Scavenger Hunt, which was based on finishing drawings of artifacts in the galleries, was aimed for Key Stage 2 students. The Advertising Campaign was a more open-ended worksheet; therefore, it was aimed for Key Stage 3 students. The Newspaper Article was a more structured form of the Advertising Campaign and can be used for either Key Stage 2 or 3. At the testing sessions it was proposed to have a more open-ended Scavenger Hunt where students have to be engaged with more than just four exhibits, so the team added more personal based questions to the Scavenger Hunt. For example, we added in a question about students' favorite exhibit in the Flight Gallery.

Throughout the project many things could not be completed due to time constraints for the project. We have a number of recommendations to improve the prototypes of the resources we developed. These recommendations include further testing, constructing picture procedures, making different level resources, and further development in the Light Upon Earth's Rotation Activity.

The most important recommendation for our designed prototypes is that they undergo further testing. Only one prototype, Balloon Rocket, was tested with students. From the testing we learned if students were engaged in the activity, the difficulty of activity, and their views to improve the activity which strengthened this resource. Therefore, we recommend that all proposed prototypes undergo further testing with students and teachers in Key Stages 2 and 3. The suggestions and views of students and teachers, the people who are going to use and implement these resources, are vital to developing effective and useful resources.

Picture based procedures (See Appendix J) are an easy way for students to see what they should be making, as well as making things more enjoyable for them. We proposed that picture procedures be developed for all resources. A template of the basic picture procedure we would like to see was created for the Spinners template. We do not expect these pictures to be used for a final design. The template was strictly created to show our basic view for the picture procedure. Along with a picture procedure, we

recommend pictures be used to explain the extensions proposed for the prototypes as well.

During our testing with teachers and staff, the idea of developing three different levels of the Scavenger Hunt was brought up. Because of our lack of understanding of the range of educational capabilities of the students within Key Stages 2 and 3 it was not appropriate for us to develop the Scavenger Hunts, but we believe that it is a great idea and we recommend it to be completed. The concept behind the levels is that students with below average, average, and above average ability will be given a Scavenger Hunt that not only challenges them but can also be completed. Also, all students would then complete their Scavenger Hunts around the same time rather than some students completing the Scavenger Hunt in less time than others, which would give us our goal that all students would be able to accomplish and complete the Scavenger Hunt.

We recommend further development of the Light Upon Earth's Rotation Activity. We extensively worked on developing this resource, and could not find a way to incorporate inexpensive materials and a hands-on aspect to the resource. The topic it covers is an extremely important one in the UK curriculum—the Earth's Rotation. From the teacher interviews and historical data, we found that many Key Stages 2 teachers would like a resource to help them teach the unit of the Earth, Sun, and Moon. For that reason we believe that with further development the activity could be extremely useful and helpful to Key Stage 2 teachers.

Lastly, recommendations to develop a resource for the Earth's tilts and its relation to seasons were proposed for further information on those recommendations refer back to section 5.2.2. We also recommend that the museum develop a Mars or Moon Lander resource for use in the classroom. For more details on that recommendation refer to section 5.2.4.

6.3 Flight Path

The Flight Path game was designed to be a fun and interactive way to teach students about the fundamentals of flight along with historical information presented in the Flight Gallery of the Science Museum in London. The goal of the game was to have a paper airplane hit a target by changing certain aspects to the paper airplane like power, angle, or elevators. The target could be located behind the thrower, or could be obstructed

by obstacles. The game incorporated ten levels each with a different historical reference in the background that was explained before each level in a pop-up. The game also has pop-ups to explain the science of flight at the end of each level. These different pop-ups within the game could be used to teach students about the history or science of flight. Also, since many of the historical content was present in the Science Museum the game could be used for use before or after a visit to the museum. This game could be easily accessed by teachers and students, and anyone else who has internet access. The game was tested by the team and during the teacher and staff testing sessions. Based on that testing, we chose to provide more detailed instructions and a better color contrast between the foreground and background.

Through an interview with a museum staff member, technical guidelines for the creation of the online interactive game, Flight Path, were determined. Flight Path had to match compatibilities with the Science Museum's game Launchball. Flight Path had to be developed on Adobe Flash[®] using Actionscript 2.0. Another guideline was that the scoring system should be based on summation of time, and each person should have unlimited lives and time to complete the game. This would allow anyone to complete the game at their own pace. Other guidelines were discussed to have the game be appropriate for the visually disabled which included a clear difference between the foreground and background of the game. Also, high contrast of colors had to be used to be able to distinguish between difficult colors. Lastly, the actual content of the game provided historical and scientific information in the form of pop-ups. This information tied into the museum and curriculum, so teachers could use the game in the classroom on an interactive whiteboard as part of a lesson or to excite students for a visit for the Flight Gallery at the Science Museum.

The recommendations for Flight Path are more general recommendations due to the nature of the design. The Science Museum does not have a development team within the Museum with the ability to further develop or change Flight Path, and the version of Flight Path we proposed will be the version utilized by the Science Museum in London. Therefore, the main recommendation for Flight Path is to test the game with students and teachers. Another recommendation is to add more levels. The added levels should follow the same format of the designed game where each background displays a

historic aircraft or place and its importance is described in the pop-up feature of the game.

6.4- General Recommendations for the Science Museum

During our project, we developed other ideas and recommendations of a more general nature for the Science Museum and the Learning Department. These recommendations are to create a checklist and level sheet for all developed resources, and to develop a Flight Kiosk.

At the student testing session, one group had an issue with the Balloon Rocket and could not figure out why their Balloon Rocket was not working. The teacher then proposed the idea of a checklist for the resource. These checklists would entail all possible issues that could occur with the resources. We recommend that a checklist be implemented for each of the resources. This would allow students to be able to check and figure out what was going wrong in the experiment themselves. The students would be able to investigate the issues without the assistance of teachers and it would promote self-investigation for students.

Also, during the student testing the teacher recommended the idea of developing level sheets for the teachers. Level sheets describe different levels of the resource, and what each student needs to accomplish to achieve each level (See Appendix CC). The level sheets are commonly used throughout the UK, but are extremely time consuming to create. If the level sheets were already created for the resource it would provide ease and less time for the teacher. Also, it would promote more independent learning and thinking by the students if they knew what had to be done to improve to the next level without the teacher having to describe it to the students.

Lastly, we recommend the Science Museum in London develops a Flight Kiosk for use in the Flight Gallery. The Flight Kiosk could be a small arcade machine located in the gallery. This would provide an interactive activity to occur in the Flight Gallery, which is currently an object-rich gallery. The Flight Kiosk could show Flight Path or another interactive flight game. The game would work by demonstrating a person's motions; for example, the person would fling their arm at a certain angle and power to throw the paper airplane in order to hit a target. The plane would then respond to those

motions in the game. This would provide a more interactive experience to visitors and possibly draw more visitors to the Flight Gallery.

After fourteen weeks of research and design, we have constructed educational resource prototypes for the classroom and Science Museum in London to help teachers educate their students on difficult topics in Space and flight. We also developed an online interactive game from the ground up, Flight Path, to describe and teach the fundamentals of flight. This online interactive game can be used to teach students within the classroom on an interactive whiteboard, or it can be used by anyone that has an internet connection. These resources will help teachers and engage students in Space and flight through fun hands-on experience. As a team we were all inspired to pursue an education and careers in science, and we feel some of those inspirations came from science museums and science activities we encountered at a young age. With this project we were able to give back and provide those opportunities we were able to experience as young students to students in the UK. We believe that these chances to enjoy and love science, along with science museums, as much as we have throughout our lives is important in order to encourage science education and careers to the UK students.

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Appendix A- Worksheet Design

Table 1

Theoretical Design Criteria for Free-Choice Worksheets and the Resulting Analysis of the Chaperone's Guide

Design Criteria for Free-Choice Worksheets ^a	Criteria Rearranged by Category ^b	Chaperone's Guide Analysis
<p>The personal context: Motivation and expectations Worksheet tasks should</p> <ul style="list-style-type: none"> • Utilize "hook" exhibits • Let learner decide which exhibit to use • Be straightforward in nature • Have clearly discernable solution(s) • Match learner age and development level • Allow time for extra exploration • Be available prior to visit 	<p>Worksheet task density should be low enough to allow time for</p> <ul style="list-style-type: none"> • Personal exploration • Interactions with museum staff • Orientation 	<p>Low task density, allowing students the opportunity to explore on their own, attend museum presentations, orient.</p> <p>7 tasks (low range), time per hall 20 min. (middle-high range), time per task 8.5 min (middle-high range).</p>
<p>The personal context: Prior knowledge, interests, beliefs Worksheet tasks should</p> <ul style="list-style-type: none"> • Connect to school curriculum • Require a variety of response formats • Be of varying cognitive levels 	<p>Orientation is facilitated by</p> <ul style="list-style-type: none"> • Use of "hook" exhibits • Availability of worksheet prior to visit • Wayfinding cues (specific and general) 	<p>Three tasks of seven use "hook" exhibits or galleries. Worksheet is available on-line. Tasks clearly marked regarding floor, gallery.</p>
<p>The personal context: Choice and control Worksheet should let user decide where and how to apply the given tasks</p>	<p>Worksheet site specificity can interfere with free-choice learning. Low site specificity allows choice in where and how to apply tasks.</p>	<p>Within galleries, four of seven tasks are nonsite specific.</p>
<p>The sociocultural context: Within-group sociocultural mediation Worksheet tasks should</p> <ul style="list-style-type: none"> • Be multiuser • Be multioutcome • Be multimodal (visual, verbal, etc.) • Use exhibits that accommodate groups 	<p>Task information source: Worksheet should emphasize</p> <ul style="list-style-type: none"> • Exhibits that accommodate groups • Object observation rather than text reading 	<p>All displays are groups accessible. Five of seven tasks call for object-dependent rather than label-dependent information.</p>
<p>The sociocultural context: Facilitated mediation by others Worksheets should allow for time to interact with museum staff, attend presentations, etc.</p>	<p>Learning is facilitated by high level of choice:</p> <ul style="list-style-type: none"> • Allowing choice in where, how to apply tasks • Providing open-ended tasks 	<p>No choice: two tasks, some choice: three tasks, subject choice: two tasks Three of seven tasks are open ended.</p>

Table 1
(Continued)

Design Criteria for Free-Choice Worksheets ^a	Criteria Rearranged by Category ^b	Chaperone's Guide Analysis
<p>The physical context: orientation and advance organizers Worksheets should</p> <ul style="list-style-type: none"> • Reflect museum wayfinding system • Provide location of pertinent exhibits • Allow time for orientation • Be available to teachers prior to visit • Use exhibits that offer conceptual coherence • Provide conceptual connections 	<p>Task cognitive level should</p> <ul style="list-style-type: none"> • Match learners' age and development level • Vary, to accommodate groups of learners • Emphasize concepts rather than facts 	<p>Tasks correspond to fourth grade developmental stage. Tasks vary in level: knowledge: two tasks, comprehension: two tasks, application: three tasks. Tasks provide opportunities for generalizing from concrete examples.</p>
<p>The physical context: Exhibit design Worksheets should be object-oriented rather than text-oriented</p>	<p>Response format: worksheet tasks should employ a variety of response formats.</p>	<p>Response format is group or individual, verbal or non-verbal, but always nonwritten.</p>
<p>The physical context: Reinforcing experiences outside the museum Worksheet tasks should connect to curriculum.</p>	<p>Other criteria:</p> <ul style="list-style-type: none"> • Worksheet should be multiuser to harness advantages of social interactions • Tasks should connect to curriculum 	<p>Worksheet is designed for group use. Worksheet tasks are all based on science curriculum.</p>

^aCategories from Falk and Dierking (2000).

^bCategories modified from Kisiel (2003).

Appendix B- Teacher Interview Questions

Teacher Interview Questions

1. Have you created or used resources to prepare students before and/or during a visit to the Science Museum? (If so, ask to explain in detail. If “no”, then ask to explain why.)
2. What type of resources do you use?
3. What are the current limitations or drawbacks of resources that you have encountered?
4. What kinds of activities do the students learn from the most?
5. Is there a noticeable split in interest towards certain exhibits between the genders and cultural groups?
6. What attributes of those exhibits appeal to the certain cultural groups and genders?
7. Have you visited the Space or Flight Gallery at all?
8. (If the answer was “yes” to the question above), If resources were to be developed for the Space and Flight Galleries, what would you like to see from them as a teacher in terms of promoting education?

Appendix C- Teacher Information

Teacher Interviews Information

Teacher	School	Age Range
1	St. Stephens CE Primary School	7-8
2	John Donne Primary School	10-11
3	Danesfeld Manor School	10-11
4	Putney High Junior School	10-11
5	Coppice Primary School	9-10
6	Haymerie School	10-11
7	Park Hill Junior School	10-11
8	Danesfield Manor School	7-9
9	Sybourn Junior School	8-9
10	Springfield First School	7-8
11	West Kingsdown CE Primary School	9-11
12	Standford Primary School	7-8
13	Moss Hall Junior School	8-9
14	Unable to obtain due to time	9-10

Appendix D- Balloon Rocket

Balloon Rocket

Educational Objective

To see the phenomenon of Newton's Third Law, which states that for every action there is an opposite and equal reaction, and how it relates to Space.

Although, Newton's Third Law is not a concept taught in the UK Curriculum for Key Stages 2 or 3 introduce the idea to the students because in our testing students were able to understand that the balloon shot down the rocket due to air being released from the balloon. Students just did not know the title of this concept was Newton's Third Law, but once introduced to the topic students were able to make a clear link the Newton's Third Law and space shuttle launches.

Key Learning

- When the balloon is let go the air escapes the balloon because the balloon wants to return to its initial state, which is the action, and as a reaction the balloon shoots across the string. This clearly displays Newton's Third Law of Motion, which states that for every action there is an opposite and equal reaction.
- For Space exploration a space shuttle uses Newton's Third Law of Motion. During the beginning stages of take off the space shuttle releases lots of Energy in the form of fuel. This causes the space shuttle to shoot upwards overcoming the forces of gravity and eventually the ozone layer.

Materials

- 1-2 long party balloons
- Plastic straw
- Dental Floss
- Sticky tape
- Two tables/chairs/desks/clamp stands
- Marker
- Ruler or Measuring tape

Procedure

This experiment should be completed in teams of 3 or more. The challenge of a race should be implemented to provide competition for the students.

- 1- Cut a straw in half. Get rid of the bendy part of the straw.
- 2- Thread the floss through the straw.
- 3- Tie the end of the floss to the two ends of the course. Make sure the floss is pulled as tight as possible.
- 4- Blow up the balloon. DO NOT TIE IT. Hold the end shut.
- 5- Hold the balloon under the straw.
- 6- Tape the balloon to the straw.
- 7- Release the balloon.
- 8- Use the pen to mark how far the balloon travelled.
- 9- Record the distance travelled.

The average distance of all the balloons can be calculated for the experiment. Also, many runs can be completed in which each group can calculate their own average distance.

Practicalities

Long party balloons work better than usual round balloons. Round balloons can be used for this experiment but a pen or pencil needs to be added to the bottom of the balloon to add weight to it.

If using latex balloons ensure there are NO latex allergies in the classroom.

The dental floss can be waxed or un-waxed. It can also be flavoured we recommend using the mint flavour for a minty fresh smell in the classroom. Do not use the end part of the dental floss roll it is not smooth enough for the Balloon Rocket to travel on.

Open-ended Investigation

For a more inquiry-based activity, ask the students to create something that can travel along the string with the furthest distance. Provide them only with materials for the experiment. You can show a test run of the Balloon Rocket and tell them to create something similar to your design. Set requirements of what the students can change and what they cannot change from your original design to make the balloon rocket travel further.

Discussion Ideas

- What is causing the balloon to shoot forward?
 - The balloon is shooting forward due to the balloon releasing air, which shows Newton's Third Law in Action.
- Which direction is the balloon moving with respect to the initial action?
 - The balloon is moving opposite of the initial action which was out of the balloon, and the balloon is moving forward as a reaction.
- Would the amount of balloons effect the outcome of the balloon rocket?

- If another balloon was added onto the rocket it would travel further due to the fact more air is being released from the balloons.
- Why is it important for space shuttles to release so much energy on take off? Besides gravity what other major barrier must a space shuttle overcome?
 - It is important for space shuttles to release so much Energy during to take off because they must overcome the force of gravity pulling them down. Also, they have to travel a very long distance meaning the initial action must cause a very big and long reaction. The other major barrier a space shuttle must overcome besides gravity is the Earth's atmosphere.

Extensions

Have two balloon rockets at each end of the string. For this extension to work the course must be straight across and pulled as tightly as possible during the experiment.

- Release them at the same time or one shortly after the other
- Have two different size balloons
 - What occurs when they collide?
 - Why does that happen?
- Explain what role forces are having in the collision

When two balloons collide at the same with equal amount of air inside the will collide and stop in the middle due to having equal forces upon collision. If one balloon is bigger then the other or released before another the one with greater force will push back on the other one with a small force.

- Have students test out different shape, size, and coloured balloons.
- Test the effect of accessories added onto the balloon such as feathers or wings.
- Have students set up a longer course along the classroom and implement a relay-race
 - One Balloon Rocket is released and when it hits the next one that Balloon Rocket is released, and so on and so forth.

Links to the Curriculum

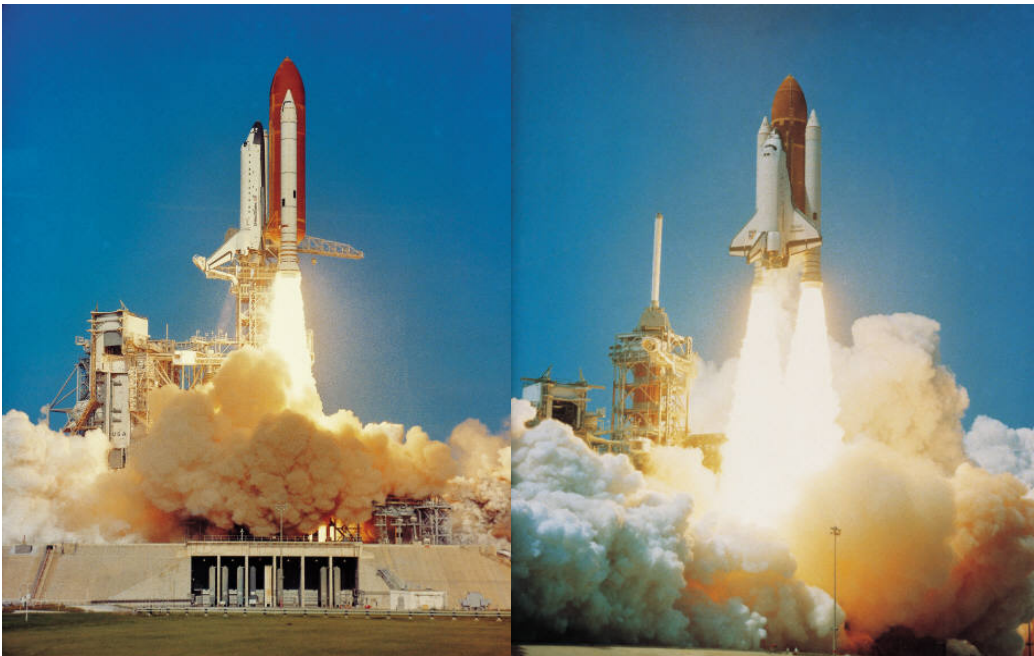
- Forces
- Solar System and Beyond
- Mathematics
 - Averages

Links to the Science Museum

- Rocket Show in Launchpad
- Space Gallery
 - Discuss historic and modern day space travel
 - What information has been received due to Space Exploration
- Gene Cerman drama character in Space Gallery
- IMAX Space Show

Links to Everyday Life

In order for a space shuttle to be launched into space scientist use Newton's Third Law of Motion, which states for every action there is an opposite and equal reaction. The scientists use this law in order to have the shuttle overcome the forces of gravity; therefore, it releases energy downward to help lift the shuttle upwards.



Fire-fighters use Newton's Third Law of Motion while fighting fires. Fire-fighters use a fire hose, which shoots out water at extremely high speeds. The force of the water coming out of the hose causes a force to react back upon the hose. For this reason many fire-fighters have to securely hold on to the hose and in order to direct it in the correct path.



Appendix E- Cuddling Balloons

Circus Activity

The following three experiments can be used together in stations or individual to explain one topic.

Cuddling Balloons

Educational Objectives

Understand the effects of air pressure on objects. Objects will move when there is a change in air pressure.

Key Learning

- A difference in air pressure can either attract or repel objects in certain directions depending on where the areas of pressure change occur.
- For example, in this experiment when students blow between the balloons the outside area of the balloons experiences a higher air pressure than in between the balloons.
- Low air pressure is observed in between the balloons because of higher air speed travelling through that area.

Materials

- 2 regular round balloons
- String or ribbon
- Coat hanger
- Water
- Scissors

Procedure

- 1- Fill a deflated balloon completely with water, without letting it expand.
- 2- Blow the balloons up to about a 45cm circumference. (about the size of a small coconut)
- 3- Tie the balloons shut.
- 4- Cut two pieces of string equal in length with scissors
- 5- Tie the string onto the ends of each balloon (one string per balloon)

- 6- Tie the other ends of the string to the bottom part of the coat hanger, the balloons should hang around 20 to 30cm long.
- 7- Make sure each balloon is tied at equal length and are separated no more than **5 cm** from each other. (DIAGRAM)
- 8- Hang the coat hanger from a stable surface so that the balloons are dangling freely in the air (at equal length). Or have someone hold the hanger steady.
- 9- Balance the balloons and ensure they are steady.
- 10- Blow in between the two balloons
- 11- Observe what occurs

Practicalities

Wire coat hangers work much better than plastic hangers, due to being very easy to tie the balloon onto.

Any type of round balloons can be used for this experiment.

Open-Ended Investigation

Set a challenge for the students to have them try to have the two balloons to touch each other. The students who do this with the maximum distance between the balloons, smallest size balloons, and in the shortest amount of time win.

Discussion Ideas

- What force is causing the results?
 - Explain why you observe those results.
 - These results occur due to a change in air pressure. When the air is blown in between the balloons low pressure is observed due to the high speed of the air travelling through. On the outside of balloons is high pressure and high pressure travels to low pressure causing the balloons to “cuddle”
- Where did you blow the air on the balloons?
 - The air was blown in the middle of the two balloons
- In what location was it most effective to blow in order to have the balloons/rolls meet one another?
 - The most effective way to do this experiment was to blow in the middle of the balloons. Although, it may have appeared that blowing at the sides would bring the balloons together it did not. The only time the balloons would touch if blowing from the sides would be if the balloons were not steady and hit each other due to that.

- Will the speed in which the air is blown affect the experiment? Why?
 - Yes, the higher the speed of the air blown the more drastic of a change to low pressure will occur. This is because the speed of the air is directly proportional to the observation and degree of air pressure.

Extensions

- Attempt to make four balloons come together.
 - How should the balloons be set up?
 - How many people do you need to blow?

During our testing of this extension we did not obtain results, but it is still a good investigation for your students, which will provoke scientific discussions. Who knows maybe your students can figure a way out we did not try.

Links to Curriculum

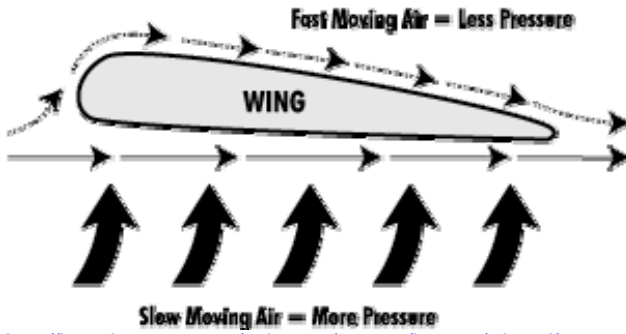
- Forces
- Pressure and its moments
- Geography and Weather

Links to Science Museum

- Flight Gallery
 - Discuss the shape of the plane and where the change in air pressure occurs
- Feel the Force Show

Links to Everyday Life

Airplanes follow the same concept when they are being designed. The designers must understand the effects of air pressure on the airplane in order to determine whether or not the plane will be capable of flying. Knowing that air pressure travels less on top of the wing and more on the bottom is the result for generating lift. This lift is what allows airplanes to fly in the sky.



<http://ksnn.larc.nasa.gov/pokemon/unseen/images/wing.gif>

Builders also use air pressure within certain tools. An air nail gun uses a change in air pressure to move the piston within the gun. With the move of the piston the gun propels the nails into deep and thick materials, such as a slab of wood.



http://www.bishop-gmbh.com/images/aircraft_design.jpg

Appendix F- Airplane vs. Bottles: The Similarities of Air Flow

Airplanes vs. Bottles:

The similarities of Air Flow

Educational Objective

Understand the need for circular shaped objects for flight, and how air travels along those objects.

Key Learning

- When you blow directly in front of a circular object the air is not stopped by this object, instead it travels around the object. This demonstrates the movement of air around objects.
- This is an important topic to understand because the ability for air to travel around an object allows the ability to fly to exist.

Materials

- Plastic circular bottle (500mL to 2L)
- Strips of paper (about 10cm long and 2.5 cm wide)
- Sticky tape

Procedure

1. Tape end of the 10cm strip of paper to table or desk.
2. Place bottle about 10cm in front of sheet of paper
3. Blow air directly at the middle of the bottle (DIAGRAM)
4. Observe movement of paper

Practicalities

The bottle can be any size, but must be circular to show the significance of an airplane's wings shape. To help the bottle stay in place about one quarter of the bottle should be filled with liquid.

Discussion Ideas

- Why is the paper moving even with a bottle directly in front of it?

- This is due to air's ability to move around circular objects. For that reason the bottle is not stopping the air from moving it is just obstructing its path forcing it to travel around the bottle.
- Describe the significance of the experiment in terms of flight.
 - This is important for flight because the shape of the wing must be circular to allow air to travel around it. This helps provide the airplane lift as well.
- Will changing the distance between the bottle and the piece of paper alter the results? Why or why not?
 - Pushing the bottle further away, will only affect the experiment if it is placed significantly further away. For example, not on the same desk as the piece of paper. If moving the bottle closer to the piece of paper no change will be seen to the experiment.
- How does the speed of the air travelling effect the fluttering of the piece of paper?
 - The faster it travels the more the piece of paper flutters.
- Draw the movement of air that occurs in the experiment. (Template for bottle)
- Draw the movement of air around a plane's wing. (Template for Wing)

Extensions

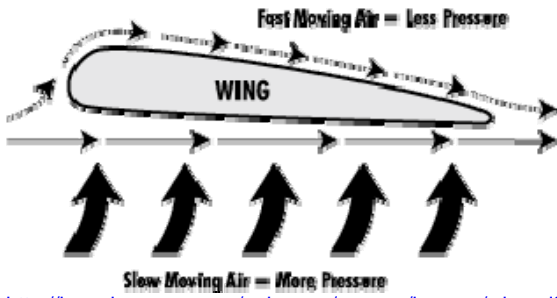
- Use different shaped and size bottles. Observe the differences or similarities in the movement of paper.
- Change the distance of the bottle from the paper along with the distance between you and the bottle.
- Try using a straw to blow onto the bottle
- Try blowing air harder and softer at the bottle.
- To study the concept of lift use the Paper Wing experiment

Links to the Science Museum

- Flight Gallery
- Discuss how air travelled over different wings throughout history

Links to Everyday Life

A wing on an airplane provides the ideal shape for air to travel over and around. When air travels over the wings of an airplane it helps provide lift for the airplane, providing it with the ability to take off.

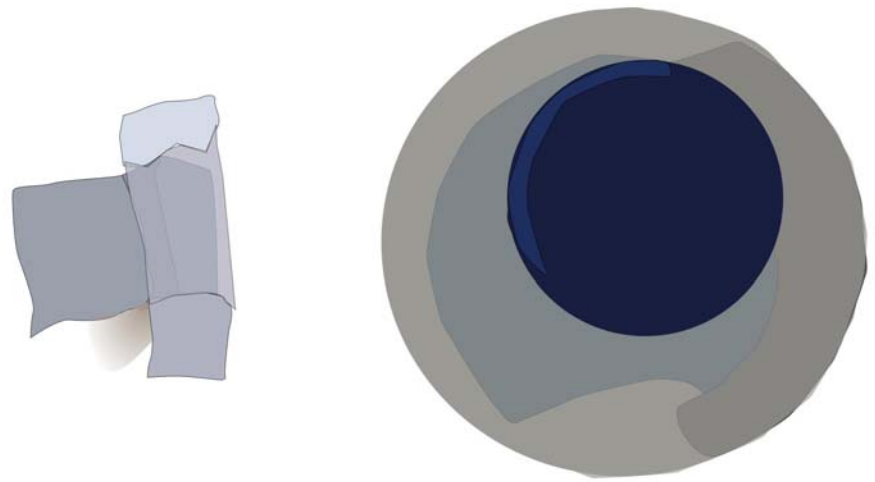


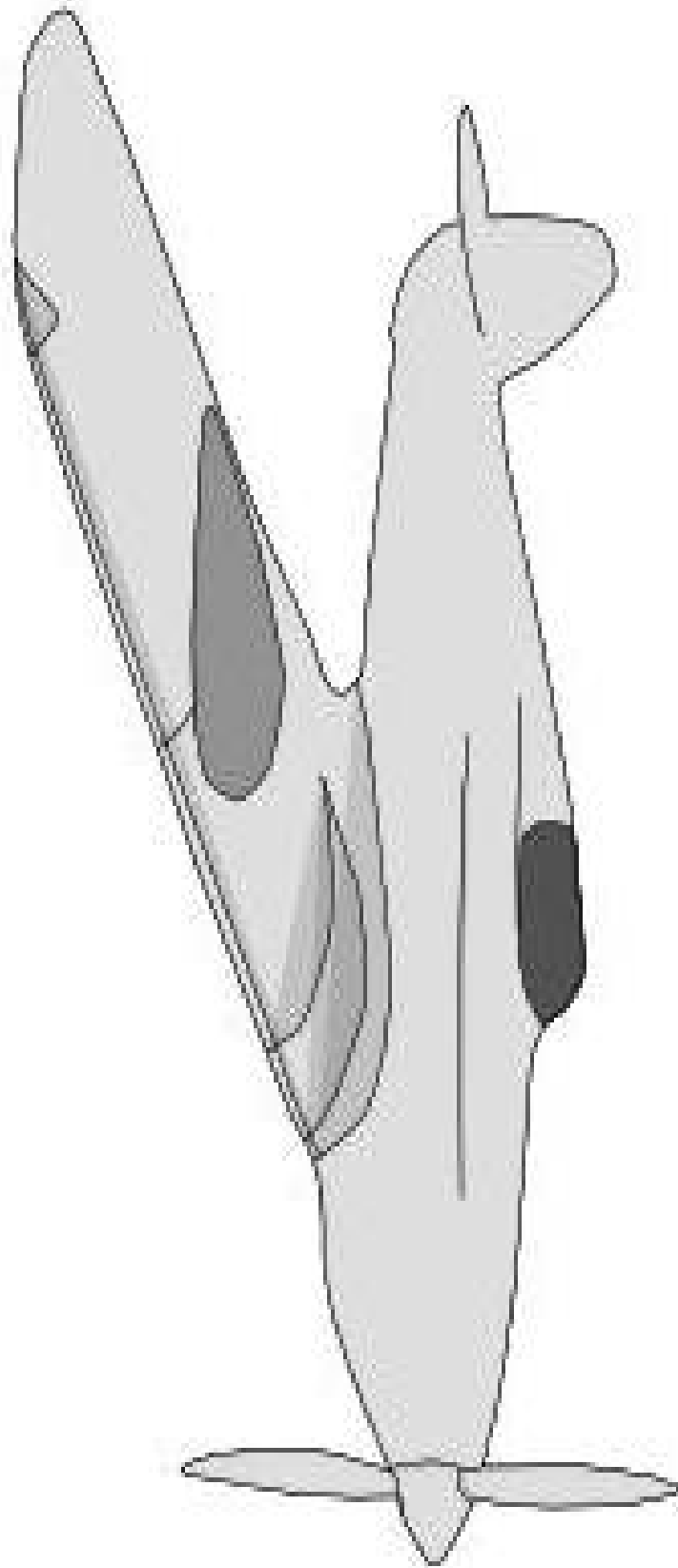
<http://ksnn.larc.nasa.gov/pokemon/unseen/images/wing.gif>

Formula one racing cars are designed with a spoiler on the end and in the front of the car. The spoilers are essentially upside down wings, and provide stability to the formula one car. When a racing car reaches high speeds it begins to lift off the ground this is because the rest of the car is essentially designed to be a wing. Therefore, the spoiler provides stability for the car to stay on the ground.



Appendix G- Worksheets for Air v. Bottle Activity





Appendix H- Paper Flyer

Paper Flyer

Educational Objectives

To show that a change in air pressure can cause objects to be lifted depending on their shape.

Key Learning

- Differences in air pressure can cause objects to be lifted depending on its shape.
- Curved or circular portions of a plane wing take a longer time for air to travel over, meaning the air must travel at a faster speed over the wing. While the air travelling along the flat surface of the wing does not have to increase its speed. These factors cause a difference in air pressure and provide lift for an airplane.

Materials

- Sheet of A4 paper
- Straw
- String in length about 60 cm long
- Sticky tape

Procedure

- 1- Fold the paper vertically.
- 2- Tape the two short ends of the paper together, still preserving the oval shape in the middle.
- 3- Make a crease at the bottom of the oval shape.
- 4- Make a hole in the middle of the folded paper.
- 5- Stick a straw through the hole.
- 6- Tape the straw to the paper.
- 7- Thread string (60cm) through the straw.
- 8- Tie knot at bottom of the string.
- 9- Hold two ends of the string.
- 10- The oval shape should be facing the ceiling.
- 11- Spin in the direction the oval side is facing.
- 12- Observe what happens.

Practicalities

Students could get dizzy during this experiment. Make sure students are taking breaks in between experiment runs.

Open-Ended Investigation

Try to have the students figure out how to generate lift with the proposed resource. Do not tell them the direction the paper wing needs to be on the string, or what must occur for the paper wing to be lifted up on the string.

Discussion Ideas

- What happened to the paper flyer?
 - What caused this?
 - The paper flyer lifted into the air. This is due to a change in air pressure. When spinning around with the paper flyer lift occurred due to the speed going across the wing making a difference in air pressure. The difference in air pressure causes the paper to lift.
- How does this relate to airplanes?
 - This relates to airplanes because they use the same concept to force lift with their airplane, and the wing of the airplane is the same shape of the paper flyer.

Extensions

- Try having students repeat this experiment with the wing placed upside down on the string.
 - Students should observe that no lift is generated with this set-up. Have students explain why this occurs, and describe the importance of the shape of the paper flyer.

Links to the Curriculum

- Forces
- Pressure and its moments

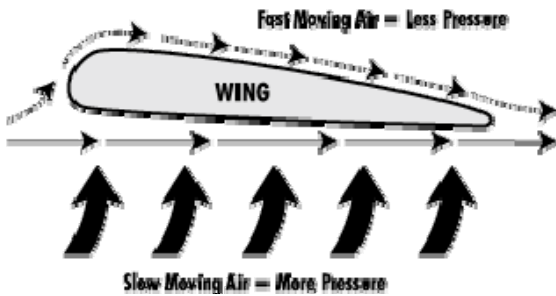
Links to the Science Museum

- Flight Gallery

- Discuss the shape of the wing and how they help generate lift for the plane
- Feel the Force Show

Links to Everyday Life

Airplanes use this concept when constructing their wings. Based on the shape of the wing, lower air pressure can travel on top of the wing while higher air pressure travels on the bottom. This generates the lift that airplanes use to fly.



<http://ksnn.larc.nasa.gov/pokemon/unseen/images/wing.gif>

Appendix I- Spinners

Spinners

This experiment can be used in the Flight Gallery or in the Classroom

Educational Objectives

To demonstrate how air influences the flight of an object based on its design.

Key Learning

- When objects with flat wings are dropped, the time it takes to travel to the ground is delayed by the resulting air resistance that acts against the object's falling motion, which causes the wings to spin.

Materials

- Paper template
- Paper clip

Extension:

- Box of paper clips

Procedure

Refer to Picture Procedure

- 1- Fold the spinner where indicated
- 2- Attach one paper clip at the base of the spinner
- 3- Release (Drop) the spinner
- 4- Observe what happens

Practicalities

The more accurate the spinner is folded in regards to the template, the better the results will be. If using in the museum, make sure that no artefacts will be interfered with in the experiment.

Open-Ended Investigation

Have students design their own spinner without using the template provided. The template can be used by the teacher to guide their students in the right direction.

Discussion Ideas

- What forces acted on the spinner?
 - In what direction to the forces act?
 - Air resistance is acting on the spinner along with gravity
 - Air resistance is working opposite the spinner and gravity is working with the spinner
- What causes the spinner to actually spin?
 - Air resistance is causing it to spin since it is pushing back on the flaps causing it to spin.
- Discuss the relationship between air resistance and speed.
 - The faster an object moves the less of an effect air resistance has on it.

Extensions

- Try this experiment using more than one paper clip or other materials such as feathers.
 - What happens to the speed of the spinner?
 - Place the paper clips in other locations
 - Does this alter the results? Why?
- Try this experiment by changing the shape and size of the spinner
 - Try rolling the base of the spinner instead of folding it (DIAGRAM)
 - Can you get the spinner to land on its base?
 - How did you achieve this?
 - What effect does each change have?
 - Explain why
- Try throwing the spinner in the air
 - Observe what happens
- Explain the affect of mass on the spinner. Why is that occurring?

Links to the Curriculum

- Forces and their effects
 - Air resistance
- Speeding Up!
 - Speed and its effect on air resistance

Links to the Science Museum

- Flight Gallery

Links to Everyday Life

Understanding how air travels through the blades of the helicopter and the importance of air resistance is critical for ensuring efficient and sustainable flight. Facilities such as hospitals and police station rely on helicopters to transport passengers or cargo over vast distances. Having this reliability allows these facilities to run smoothly and adequately.



<http://www.truckeefire.org/images/images/Careflight%20lifting%20pad.jpg>

http://lh3.google.com/_qtf_vzoBbaw/RkSZhXEsKxI/AAAAAAAAANc/M4kQ_RT4dDw/s800/100_0066.JPG

Skydivers and army paratroopers use the force of air resistance with every jump they take. When jumping out of an airplane the force of gravity is pulling them down to Earth. The paratroopers then release their parachute. Releasing their parachute allows the force of air resistance to counteract the force of gravity. This allows the paratroopers to safely reach the ground.



<http://www.army.mil/nz/nr/rdonlyres/106e6e3e-f65a-42a0-818d-29d1728ffde2/0/wn06003342.jpg>

http://www.blackfive.net/main/2005/09/paratroopers_at.html

Appendix J- Spinners Picture Procedure

SPINNERS

Are you extreme enough to fly your own helicopter? Practice your skills with this paper version.

What you will need...



Rip template into two



Rip down middle to create flaps and fold in opposite directions



Rip along solid line and fold in



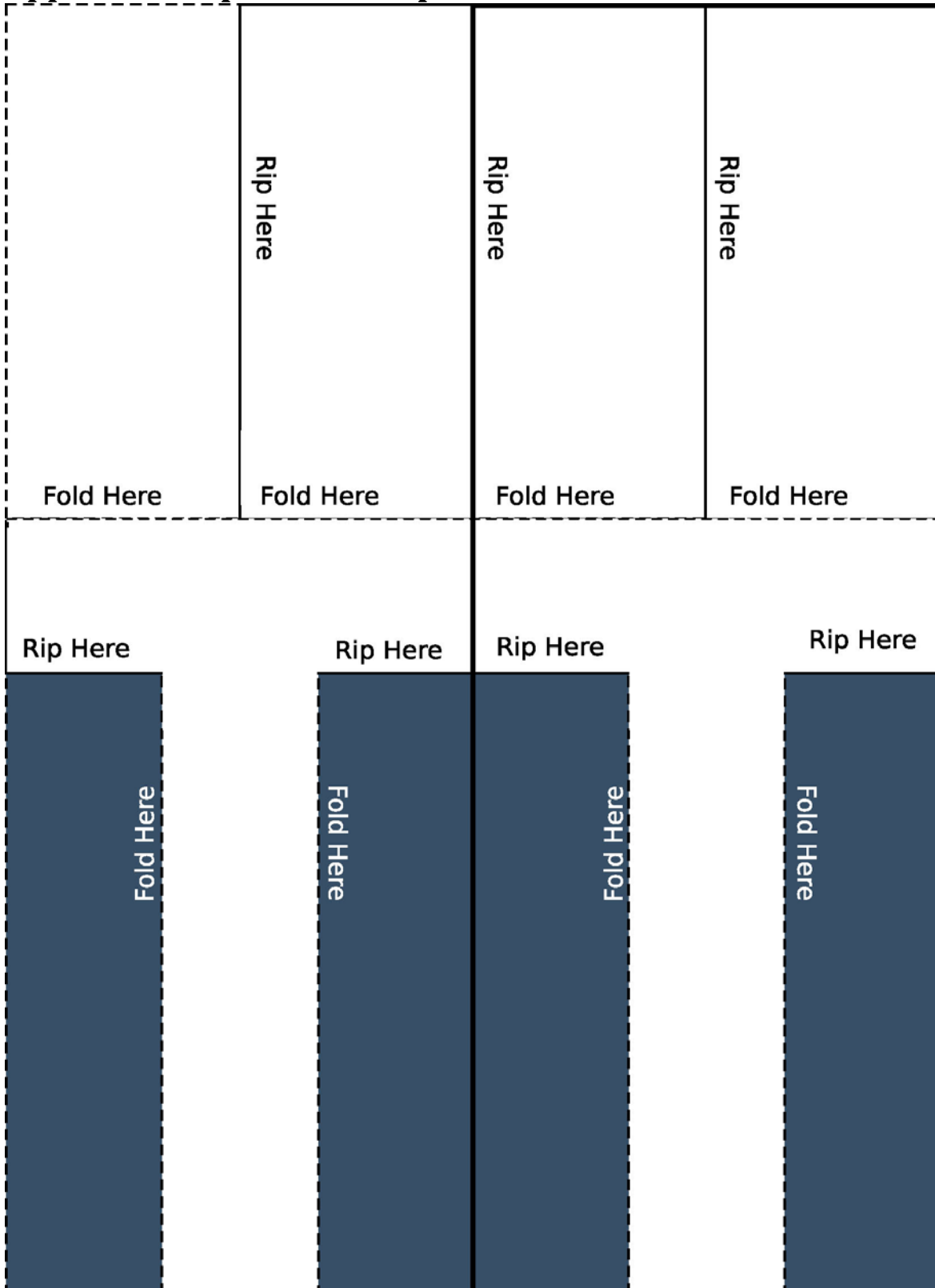
Repeat for other side



Drop it down and let it spin!



Appendix K- Spinners Template



Appendix L- Three Alternatives for the Space Scavenger Hunt

NAME:

DATE:

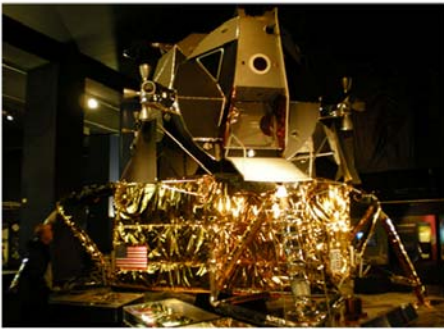
Congratulations!! You have just been certified as a Genuine Space Cadet by the European Space Agency. For your mission, operation "Seek and Restore", find the images in the photographs and draw in what was lost. We are counting on you to complete the photographs of the objects accurately.

To make sure that no errors occur:

- Observe the objects and match it with its photograph
- Through the questions provided, show proof that the object in the photograph matches your selection of the object in the gallery

Good luck!!!!

Landing on the Moon (Hint: go find the exhibit of the picture on left)



Why did Apollo astronauts leave instruments on the Moon's surface?



If you had a chance to leave something on the moon what would it be and why?

What object from the Space Gallery do you like the most? Draw the object below.



NAME:

DATE:

Space Rockets



What do you think it would feel like to travel in a rocket to space?

If you had a rocketship what planet would you travel to and why?

Voyage of the Beagle

What was the mission of the Beagle?



If you were to look for signs of life on another planet, what would you look for?

Congratulations!! You have successfully completed your mission! You are indeed a worthy Space Cadet. For your hard work, the Science Museum is honoured to promote you to a Genuine Space Captain.

NAME:

DATE:

Congratulations!! You have just been certified as a Genuine Space Cadet by the European Space Agency. For your mission, operation "Seek and Restore", find the images in the photographs and draw in what was lost. We are counting on you to complete the photographs of the objects accurately.

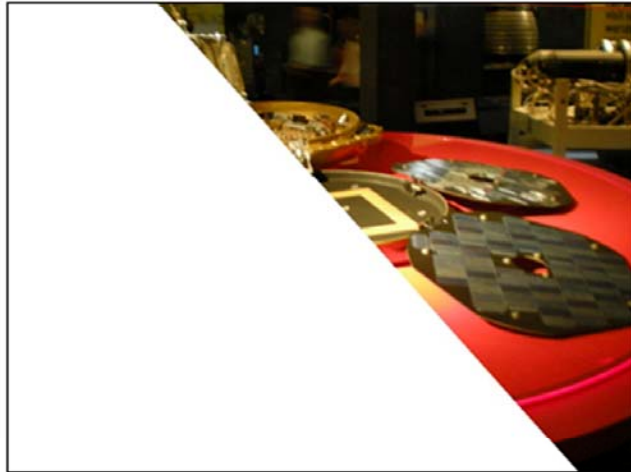
To make sure that no errors occur:

- Observe the objects and match it with its photograph
- Through the questions provided, show proof that the object in the photograph matches your selection of the object in the gallery

Good luck!!!!

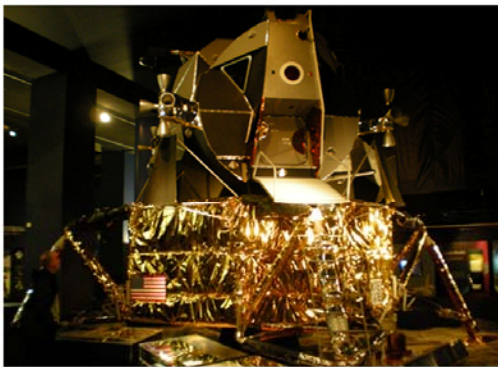
Voyage of the Beagle

What was the mission of the Beagle?

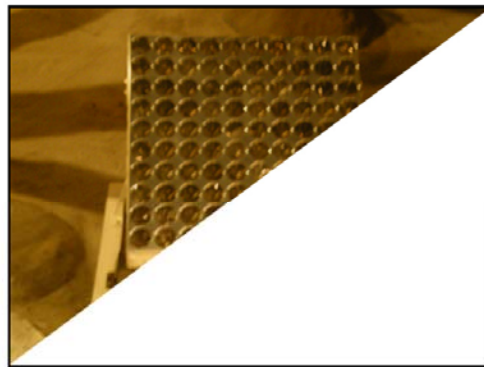


If you were to look for signs of life on another planet, what would you look for?

Landing on the Moon (Hint: go find the exhibit of the picture on left)



Why did Apollo astronauts leave instruments on the Moon's surface?



If you had a chance to leave something on the moon what would it be and why?

NAME:

DATE:

What object from the Space Gallery do you like the most? Draw the object below.



Space Rockets



What do you think it would feel like to travel in a rocket to space?

If you had a rocketship what planet would you travel to and why?

Congratulations!! You have successfully completed your mission! You are indeed a worthy Space Cadet. For your hard work, the Science Museum is honoured to promote you to a Genuine Space Captain.

NAME:

DATE:

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- Through the questions provided, show proof that the object in the photograph matches your selection of the object in the gallery

Good luck!!!!

Space Rockets



What do you think it would feel like to travel in a rocket to space?

If you had a rocketship what planet would you travel to and why?

Voyage of the Beagle

What was the mission of the Beagle?

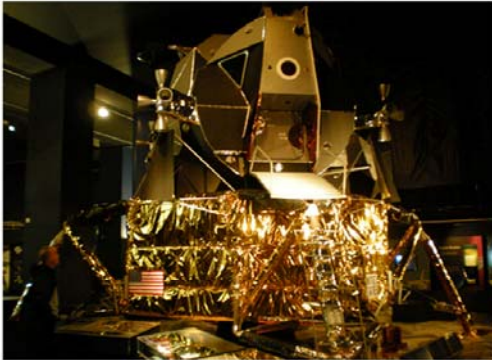


If you were to look for signs of life on another planet, what would you look for?

NAME:

DATE:

Landing on the Moon (Hint: go find the exhibit of the picture on left)



Why did Apollo astronauts leave instruments on the Moon's surface?



If you had a chance to leave something on the moon what would it be and why?

What object from the Space Gallery do you like the most? Draw the object below.



Congratulations!! You have successfully completed your mission! You are indeed a worthy Space Cadet. For your hard work, the Science Museum is honoured to promote you to a Genuine Space Captain.

Appendix M- Three alternatives for the Flight Scavenger Hunt

NAME:

DATE:

Congratulations!! You have just been certified as a Genuine Flight Cadet by Boeing. For your mission, operation "Seek and Restore", find the images in the photographs and draw in what was lost. We are counting on you to complete the photographs of the objects accurately.

To make sure that no errors occur:

- Observe the objects and match it with its photograph
- Through the questions provided, show proof that the object in the photograph matches your selection of the object in the gallery

Good luck!!!!

Gloster E.28/39, 1941



What was so special about this aircraft's engine?

What do you think it would be like to be a jet pilot?

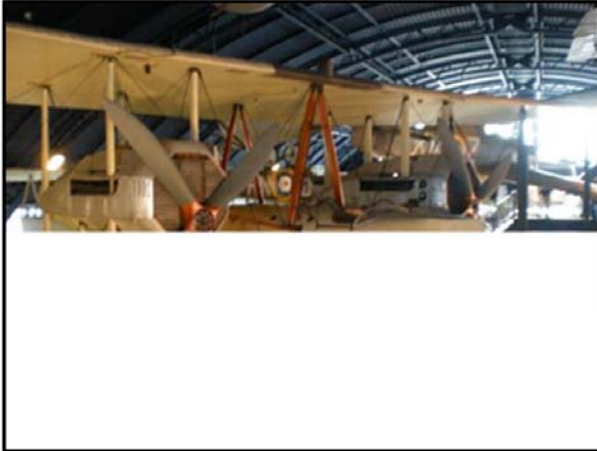
Draw your favorite plane in the Flight Gallery that is not mentioned in the Scavenger Hunt.



NAME:

DATE:

Vickers Vinny, 1919

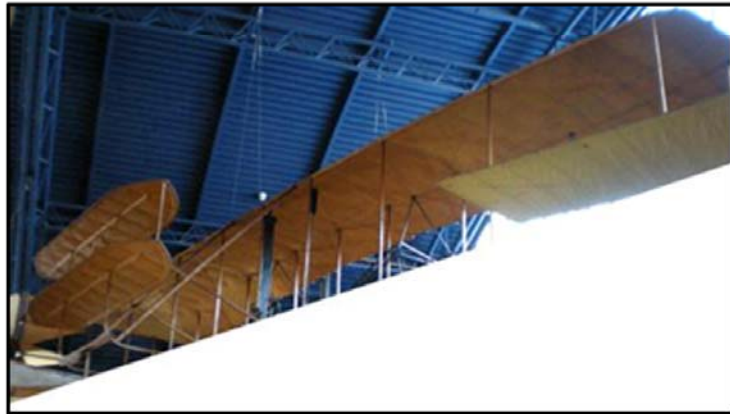


Across what ocean did this aircraft once fly over?

If you had a choice to be the first person to fly anywhere around the Earth, where would you fly? Why?

When did the Wright Brothers launch the first successful flight?

First Flight



The Wright Brothers were the first to fly, what would you like to be the first person to do?

Congratulations!! You have successfully completed your mission! You are indeed a worthy Flight Cadet. For your hard work, the Science Museum is honoured to promote you to a Genuine Flight Captain.

NAME:

DATE:

Congratulations!! You have just been certified as a Genuine Flight Cadet by Boeing. For your mission, operation "Seek and Restore", find the images in the photographs and draw in what was lost. We are counting on you to complete the photographs of the objects accurately.

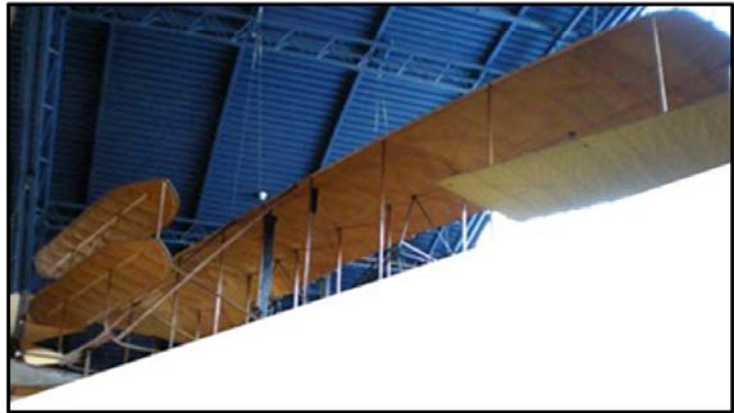
To make sure that no errors occur:

- Observe the objects and match it with its photograph
- Through the questions provided, show proof that the object in the photograph matches your selection of the object in the gallery

Good luck!!!!

First Flight

When did the Wright Brothers launch the first successful flight?



The Wright Brothers were the first to fly, what would you like to be the first person to do?

Gloster E.28/39, 1941



What was so special about this aircraft's engine?

What do you think it would be like to be a jet pilot?

NAME:

DATE:

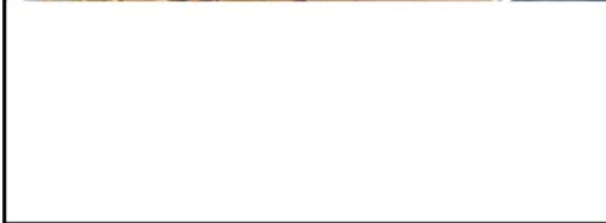
Draw your favorite plane in the Flight Gallery that is not mentioned in the Scavenger Hunt.



Vickers Vinny, 1919



Across what ocean did this aircraft once fly over?



If you had a choice to be the first person to fly anywhere around the Earth, where would you fly? Why?

Congratulations!! You have successfully completed your mission! You are indeed a worthy Flight Cadet. For your hard work, the Science Museum is honoured to promote you to a Genuine Flight Captain.

NAME:

DATE:

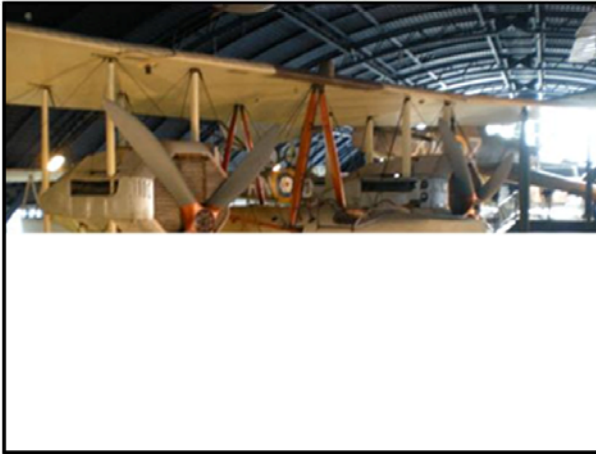
Congratulations!! You have just been certified as a Genuine Flight Cadet by Boeing. For your mission, operation "Seek and Restore", find the images in the photographs and draw in what was lost. We are counting on you to complete the photographs of the objects accurately.

To make sure that no errors occur:

- Observe the objects and match it with its photograph
- Through the questions provided, show proof that the object in the photograph matches your selection of the object in the gallery

Good luck!!!!

Vickers Vinny, 1919

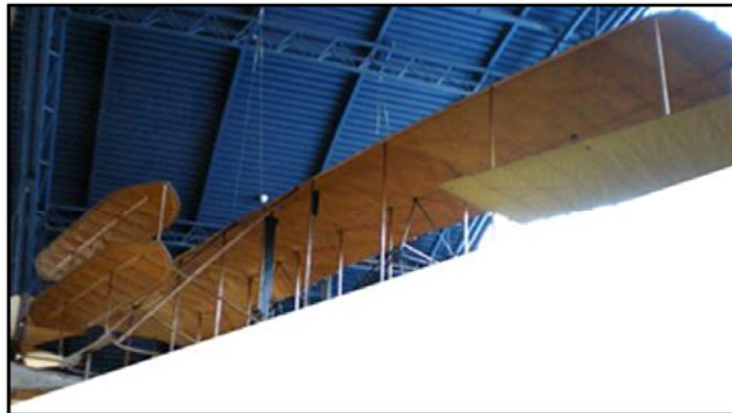


Across what ocean did this aircraft once fly over?

If you had a choice to be the first person to fly anywhere around the Earth, where would you fly? Why?

When did the Wright Brothers launch the first successful flight?

First Flight



The Wright Brothers were the first to fly, what would you like to be the first person to do?

NAME:

DATE:

Gloster E.28/39, 1941



What was so special about this aircraft's engine?

What do you think it would be like to be a jet pilot?

Draw your favorite plane in the Flight Gallery that is not mentioned in the Scavenger Hunt.



Congratulations!! You have successfully completed your mission! You are indeed a worthy Flight Cadet. For your hard work, the Science Museum is honoured to promote you to a Genuine Flight Captain.

Appendix N- Imperial War Museum Worksheet



EDUCATION
SERVICE

LARGE EXHIBITS GALLERY
FIRST WORLD WAR



Name _____ School _____

As the First World War developed into a long drawn out conflict, changes in the kinds of weapons and technology used were inevitable as each side tried to break the dead lock on the land, on the sea and in the air. *(Remember to look at photographs and captions to help you.)*

1 GROUND FLOOR

- a Starting in the middle of the gallery, find this figure on the bus.**

He was a famous First World War cartoon character called "Ole Bill." Transport like this London bus was used to carry troops on the Western Front. How was the bus altered for this kind of service?

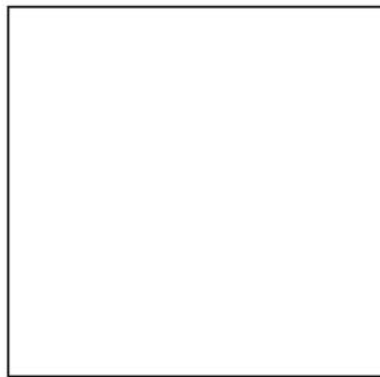


- b** Apart from transporting soldiers what other purpose were these vehicles used for?

2 Find the British First World War Mark V Tank.

Tanks were designed to break the deadlock of trench warfare by demolishing barbed-wire and flattening trenches.

- a** Draw the emblem that is painted on the side in the box below.



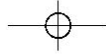
- b** What is the tank's nickname?

- c** Look carefully at the layout of the interior and the photograph and caption.

How many men were there in the crew?

- d** Describe what you think the conditions would have been like for the crew during a battle. (N.B. the terrain of the Western Front)





3 Find the German Mast Periscope.

a look through the periscope. What can you see?

b Why was such a device developed in the First World War?

c What alternatives could be used for the same purpose?

d What observation device was used by soldiers in the trenches? _____

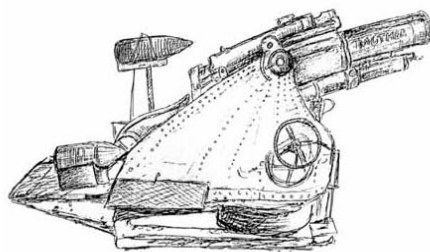
(You will find examples in the First World War Exhibition. The illustration above will help.)

4 Large guns were very important weapons on the Western Front. Fill in the table below stating the advantages and disadvantages of 2 of these.

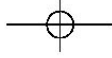
Look carefully at the guns and the captions.

a

French 75mm Field Gun		British Mark I, Heavy Siege Howitzer	
Advantages	Disadvantages	Advantages	Disadvantages



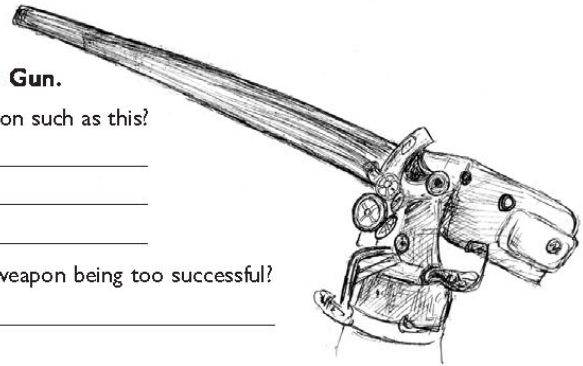
b In your opinion which was better suited to trench warfare and why?



5 Find the German 10.5cm Submarine Gun.

a Why was a submarine armed with a weapon such as this?

b How did the Allies try to prevent such a weapon being too successful?



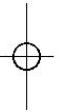
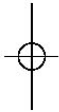
6 Find the British 5.5 Naval Gun Mark I from HMS Chester:

a Find the brass sight-setting disc on the left hand side of the gun. Who was responsible for adjusting this?

b How old do you think he is from the photograph?

c What happened to him on 31 May 1916?

(you will find out more about him in the Victoria Cross and George Cross Gallery on the First Floor level.)



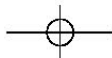
Go up to the First Floor Gallery Level

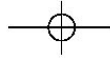
7 Find the Observation Car from a German Zeppelin. (Airship)

a How long was the steel cable that attached this to the zeppelin?

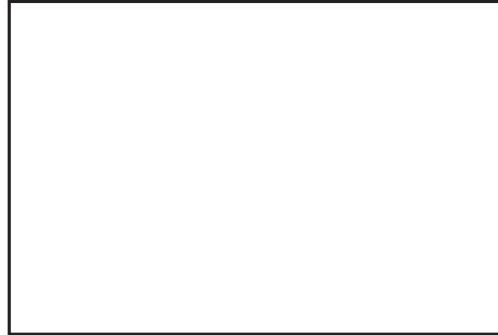
b With this in mind and by looking at the diagram, why was it considered important for observers to be in this car rather than in the main carriages where most of the crew were stationed?

c How did the observer in the car communicate with the rest of the crew?





- d Imagine what it would have been like to travel in this.
How would you have felt?



- e Draw the observation car in the box.

Go up to second floor gallery level balcony.

- 8 Air warfare was in its infancy in 1914 (NB the first manned flight had only happened in 1903 in America with the Wright brothers). The air service was divided into the Royal Flying Corps (RFC) linked to the army and the Royal Naval Air Service (RNAS) linked to the navy. By 1918 the two merged to form the Royal Air Force (RAF), the first independent air service in the world.

Find the First World War biplane the BE2c. (cream coloured)

- a What was this aircraft and all early aircraft primarily designed to do?

- b Why was it not suited to aerial combat?



Find the Sopwith Camel. (dark green coloured)

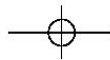
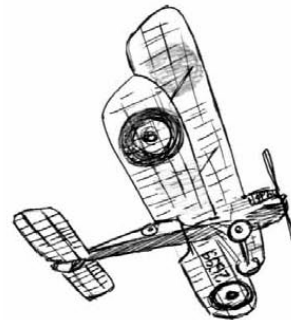
Look carefully.

- c How has the problem of firing from the plane been solved?

- d This particular aircraft was used to protect who from what?

- e What do you think is the basic framework of these aircraft and how does this differ from the Second World War aircraft near by?

- f What do you think are the advantages that aircraft of the Second World War have over those of the First World War?

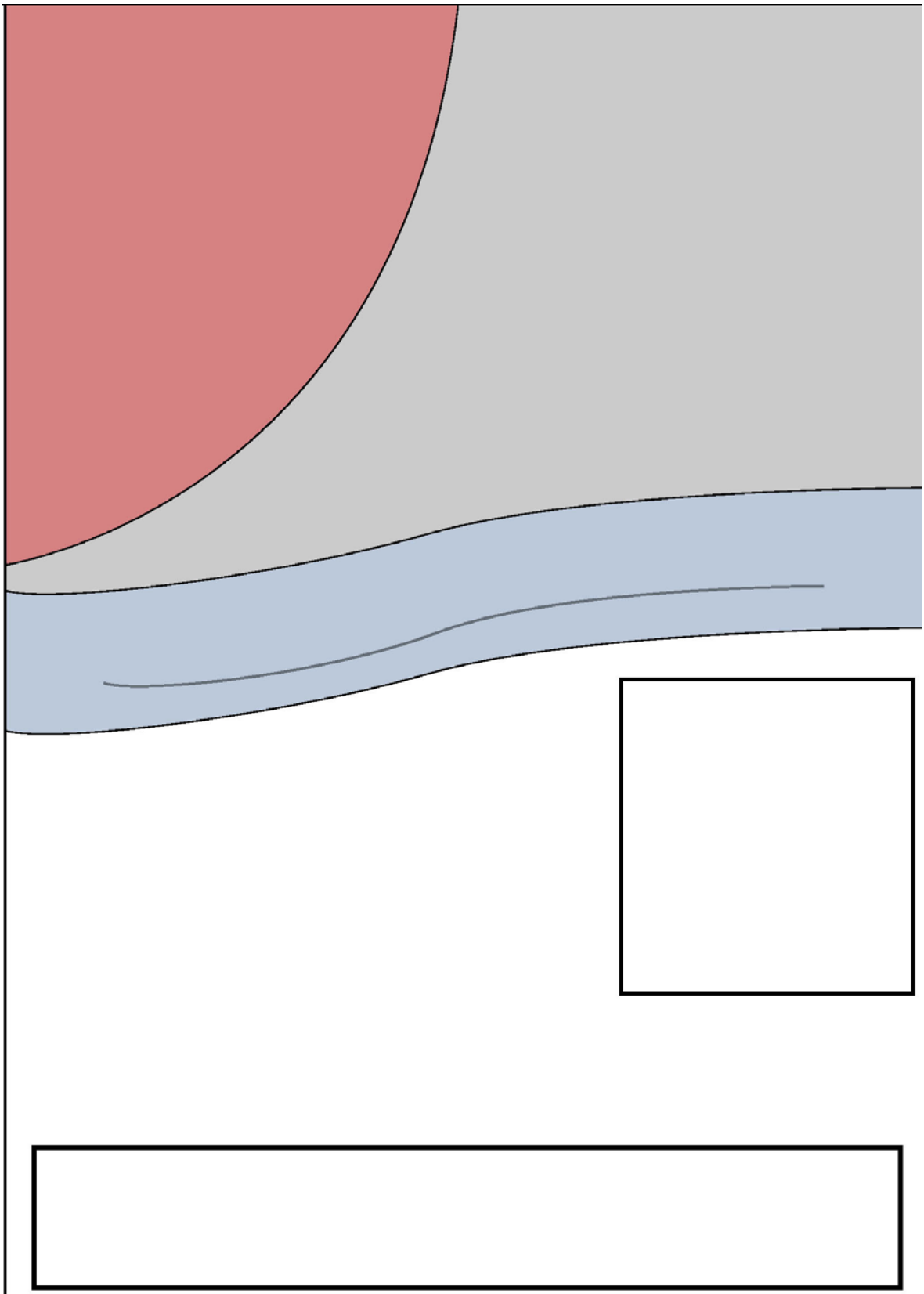


Appendix O- Space Advertisement Campaign

If We Could Ad Them Together Surely We'd Get Something

The European Space Agency needs qualified people to become astronauts. That is why we, the High Orbit Advertisement Agency, have been put on the job to recruit new astronauts. Oh no! Our graphic designer has had an unfortunate accident! How are we going to finish the advertisement by today's deadline?

Luckily you have arrived right on time. It is now up to you to finish the advertisement. Draw an advertising campaign to convince future astronauts of why Space and Space Exploration is a fascinating topic. Our graphic designer has left you with an early design but the rest is up to you. Any and every part of the design given is available for you to use however you choose. You can draw in as many pictures and/or information as you'd like. The mission is simple. Do you have the right stuff?

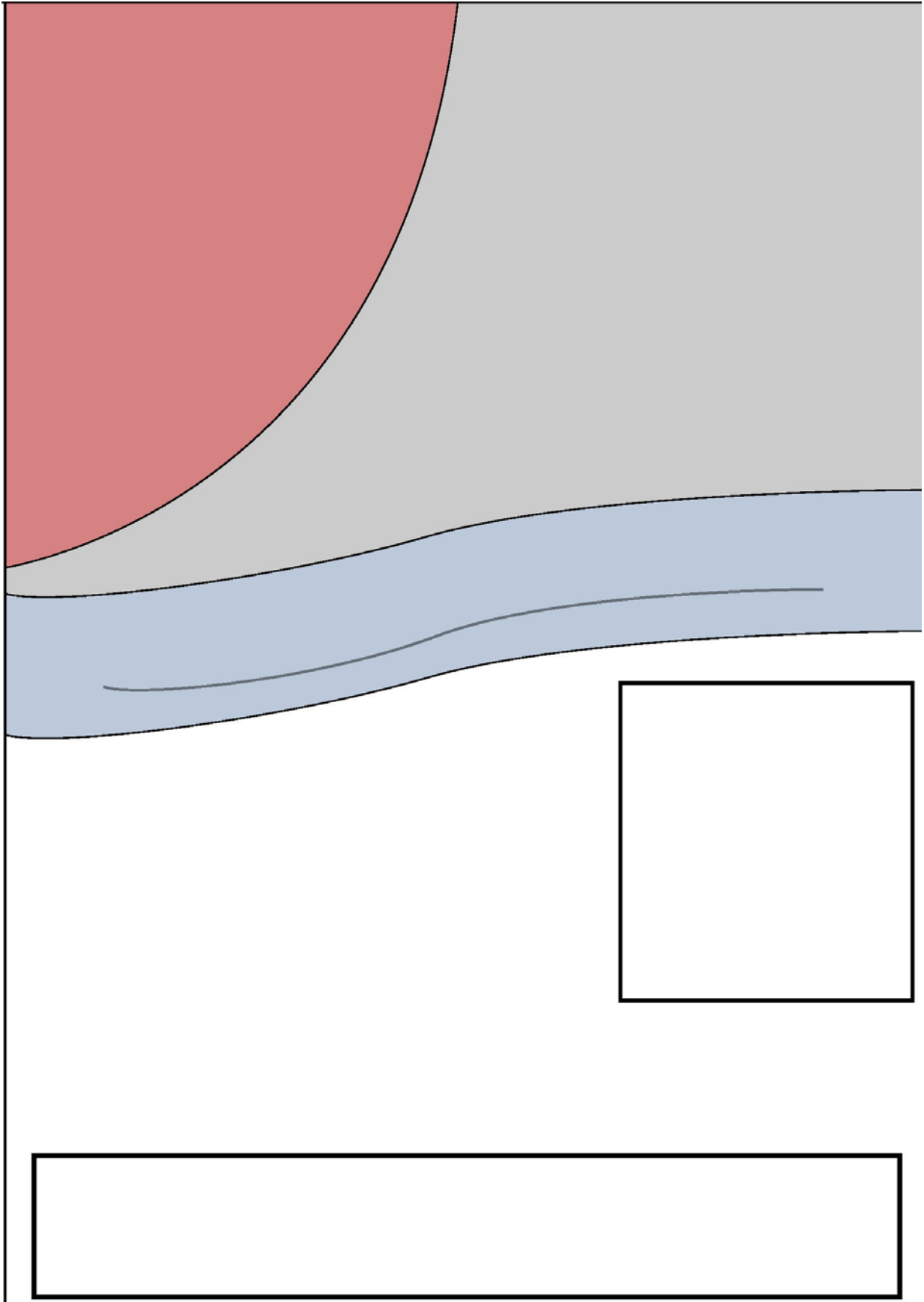


Appendix P-Flight Advertisement Campaign

If We Could Ad Them Together Surely We'd Get Something

Oh no! Our graphic designer has been in an accident! How are we going to finish the advertisement for the Flight Gallery by today's deadline?

Luckily you've arrived right on time. It is now up to you to finish the advertisement. Pick an exhibit in the Flight Gallery and draw an advertising campaign. Our graphic designer has left you with an early design but the rest is up to you. Any and every part of the design provided is available for you to use however you choose. You can draw in as many pictures and/or information as you'd like. The mission is simple. All you have to do is convince fellow classmates to come visit the Flight Gallery. Do you have the Wright stuff?



Appendix Q- Flight Newspaper Article

Newsflash!

The News is always Wright

Ever hear of a slow news day? Well, this is the opposite. There's in fact so much news the paper had to push its planned feature on the Flight gallery into a special section called "The Wright Enterprise." While all of our journalists and editors are busy working the latest event, nobody has time to work on this section. It is now up to you to complete our special feature on the Flight Gallery. Use the lines provided to draw and write about an exhibit and its benefits to society. With your expert reporting we won't have to stop the presses.

THE WRIGHT ENTERPRISE

BY:

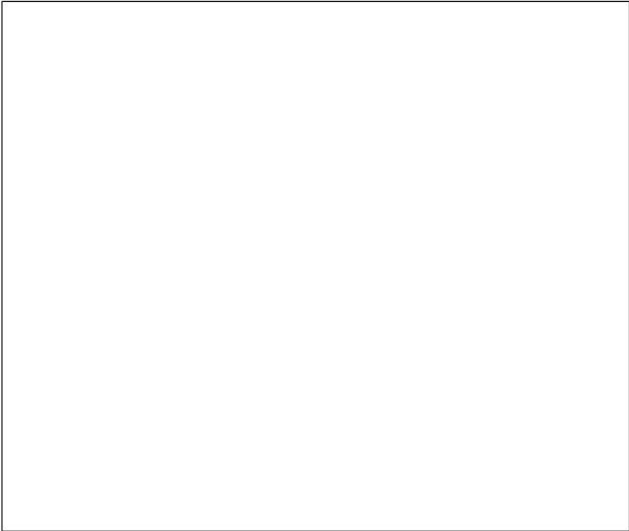
This day in History



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“The best exhibit in all of the Flight Galley”

Appendix R- Space Newspaper Article

Newsflash!

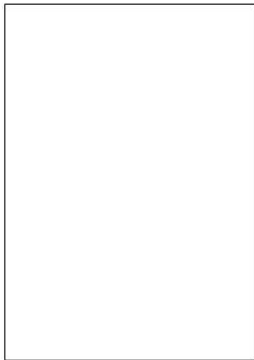
There's always Space for News

Ever hear of a slow news day? Well, this is the opposite. There's in fact so much news the paper had to push its planned feature on the Space gallery into a special section called "The Daily Orbit." While all of our journalists and editors are busy working the latest event, nobody has time to work on this section. It is now up to you to complete our special feature on the Space Gallery. Use the lines provided to draw and write about an exhibit and its benefits to society. With your expert reporting we won't have to stop the presses.

THE DAILY ORBIT

BY:

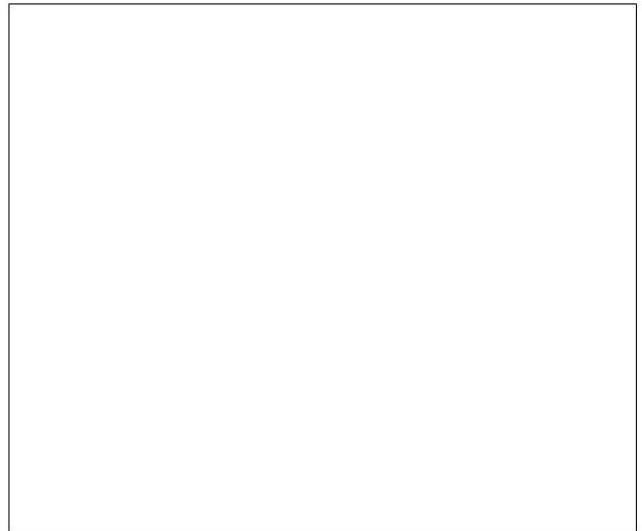
This day in History



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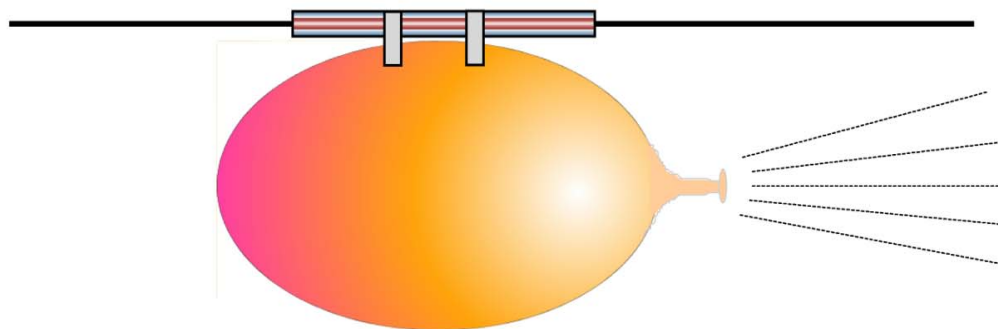
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“The best exhibit in all of the Space Galley”

Appendix S- Balloon Rocket Procedure for Student Testing

Rocket Balloon



<http://www.creative-chemistry.org.uk>

1. Cut a straw in half. Get rid of the bendy part of the straw.
2. Thread the straw through the floss.
3. Tie the end of the floss to either two ends of the course. Make sure the floss is pulled as tight as possible.
4. Blow up the balloon. DO NOT TIE IT. Hold the end shut.
5. Hold the balloon under the straw.
6. Tape to the balloon to the straw.
7. Release the balloon.
8. Use the pen to mark how far the balloon travelled.

For the Extension:

1. Use two half straws
2. Thread straw through floss
3. Repeat Steps 3 and 6 from first procedure
4. Place the balloons rockets on opposite ends so they will head for each other
5. Release the balloons
6. Observe what happens upon collision

Appendix T- Test Runs of Rocket Balloon

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	1 m course Regular balloons Cut Straw in Half Dental Floss	Worked great	longer track
2	3 m course clothes peg to keep air from escaping balloon Regular balloons	pegs failed Worked	No need for fishing line since more expensive, dangerous, and hard to find longer course possible extension-use to slowly release air
3	7m course Extension with clothes pegs Regular balloons	longer track worked better Failed spin around the dental floss during travel	use 7m course rest of test Try alligator or crocodile clip Need average size to blow it up to
4	Re-attempt of Test Run 3	Worked	
6	Re-attempt of Test Run 3	Worked	
5	Two Regular balloons on straw One top and One bottom Both Taped to straw	Top balloon fell off after traveling 2 m Overall failed	Blow up regular balloon to about 20cm around Cup extension will not work with round balloon just due to observation of the cup size and balloon size
6	Two balloons Wrapped onto each other One tapes closed to slowly release air	Slowly propelled forward didn't stay on long Failed, and not easy to perform	Stick to just one balloon per straw
7	Long balloons	Worked much better Represented a rocket more then regular balloons Travelled further Around 35 cm in length	
8	Re-attempt of Test Run 7	Worked	Keep length around 30-40 cm
9	Re-attempt of Test Run 7	Worked	
10	Add cup to nose of the long balloon	Fell off too quickly balloon did not move	Try blowing up the balloon less to have cup fit better Get rid of cup experiment does not show what was expected
11	Re-attempt with cup Blew up balloon to 30cm in length		
12	Add weight to bottom of regular balloon Place pen on bottom	Keeps balloon from spinning over the fishing line Travelled further Pen fell off at the end	
13	Re-attempt with pen as weight	Pen fell off at the end again Travelled further balloon did not spin	Use more tape to keep pen on
14	Re-attempt with pen as a weight Added more tape to pen	Worked well Pen stayed on	Attempt to use other materials as weight
15	Weigh down regular balloon with ruler	Ruler too heavy Weighed down balloon didn't move	
16	Weigh down regular balloon with dry-erase marker	Still too heavy Travelled little distance (10 cm)	
17	Weigh down regular balloon with pencil	Worked same as pen	Can use either pen or pencil to weight down regular balloon Add into materials and procedure if using regular balloon
18	Long vs Regular balloon Side by side runs on separate course	Floss to close together Strings tangled	Move strings further apart
19	Long vs Regular balloon Side by side runs	Long balloon went further No weight on the regular balloon	Add weight to regular balloon

Test Run	Set Up	Notes/Results	Conclusion/ Changes
20	Long vs Regular balloon Weight placed on regular balloon	Long balloon didn't travel very far due to the extension part of the straw bending	Can't use straws that have extension part
21	Long vs Regular balloon	Failed due to recycling box in the way	
22	Long vs Regular balloon Twist end of balloon, clip with clothes peg	Air did not come out Long balloon travel full length of course Regular balloon got stuck when clothes peg released	
23	Long vs Regular balloon Clothes peg used to keep air in balloon attached to straw remove clothes peg Hold by hand at that point	Long balloon went full 7m Regular balloon went 10cm short of the full course	Clothes peg used for rest of testing for convenience in construction New balloons should be used every 3 runs prevents stretching and sticking together of balloon
24	Long vs Regular balloon Same as Test Run 23	Long balloon travelled full 7m Regular balloon travelled 5.5m	
25	Long vs Regular balloon Same as Test Run 23	Regular travelled about 6.5 m Long balloon travelled about 6.6m Regular balloon had more air in the long balloon	Regulation for amount the balloon is blown up need to be made Long balloon travel further and are easier to use since no weight is needed Regular balloon doesn't work as well but are easier to find
26	Two balloons same course Head for another Regular balloon	Hit in middle and stopped Results we wanted, but didn't look like them	
27	Two balloons same course Head for another Regular balloon	Hit in middle and stopped Appears like it ran out of air not that equal forces caused it to stopped	Try with long balloons
28	Two balloons same course Head for another Long balloons	Hit in middle One kept pushing forward Air not equal in both balloons Not identical release times	
29	Two balloons same course Head for another Long balloons	One travelled much further then other Collided; one that didn't travel as far pushed other balloon back Not results we wanted	Unrealistic to get two to stop in the middle No longer attempting to get them to stop in the middle Open ended investigations; students send two balloons to other and explain whatever results occur
30	Effect of things taped to the side Long balloons without paper Length of Balloon: 38.5cm With copy paper Length of Balloon: 39.2cm	Distance: 7m Distance: 5.24m	
31	Effect of things taped to the side Long balloons without paper Length of Balloon: 39.1cm With copy paper Length of Balloon: 40 cm	Distance: 6.24m Distance: 5.85m	
32	Effect of things taped to the side Long balloons without paper Length of Balloon: 39.0cm With copy paper Length of Balloon: 39.3cm	Distance: 6.93m Distance: 4.04m	Tests 30-32 showed taping paper to sides of balloon rocket does have an effect on its travel, but it still works effectively and travels far enough along the course.

Appendix U- Test Runs of Paper Wing

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	Copy Paper Held piece of folded paper in middle	Didn't work	
2	Same paper Held at the flat base	Worked	
3	Re-attempt of Test Run 2	Worked	
4	Re-attempt of Test Run 2	Worked	Holding flat base of paper at end works
5	Same materials Press down on ends of paper	Loss of flat surface Did not work very well	
6	Re-attempt of Test Run 5	Worked	
7	Re-attempt of Test Run 5	Worked	Although it worked much more effective results from holding paper on ends at the flat base
8	Flipped wing around oval side Oval side facing you	Did not work	Must have flat end facing you
9	Used thicker paper	Worked, not as well	Not as easy or cheap as copy paper Use of copy paper for experiment

Appendix V- Test Runs of Paper Flyer

Test Run	Set Up	Notes/Results	Conclusion/Changes
1	Red string Modified paper wing shape (oval shape on top) Cut straw Spin in direction of oval shape	Worked	Clearer way to see lift in relation to wing shape
2	Re-attempt Test Run 1	Worked	
3	Re-attempt Test Run 1	Worked	Add knot to bottom of string, keeps paper wing on string
4	White string Modified paper wing shape (oval shape on top) Cut straw	Worked	
5	Re-attempt Test Run 4	Worked	
6	Re-attempt Test Run 4	Worked	Type of string does not vary results
7	Turn wing upside down (oval shape on bottom)	Did not work	Discussion question on why it only works with oval shape on top
8	Spin in opposite direction of oval side	Did not work	Discussion on air flow over the paper wing Discussion on Why does it only work spinning one way?

Appendix W- Test Runs of Air v. Bottle: Similarities in Air Flow

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	2 liter bottle 10cm piece of paper distance between two 20cm	Worked Had to blow a little too hard	Bring bottle closer to paper
2	Same materials distance between two 10cm	Worked much better	
3	Re-attempt of Test Run 2	Worked	
4	Re-attempt of Test Run 2	Worked	
5	Same materials distance between two 5cm	Worked	Did not get same effect of air travelling Distance should be 10cm apart
6	Same distance 500 mL bottle	Worked Bottle moved with blowing	Add small amount of water to keep it in place
7	Re-attempt of Test Run 6	Worked	
8	Re-attempt of Test Run 6	Worked	
9	Same distance 591 mL bottle	Worked	
10	Re-attempt Test Run 9	Worked	
11	Re-attempt Test Run 9	Worked	
12	Use straw to blow 591mL bottle	Worked	
13	Re-attempt of Test Run 12	Worked	
14	Re-attempt of Test Run 12	Worked	
15	Use Straw to blow 2 Liter	Worked	
16	Re-attempt of Test Run 15	Worked	
17	Re-attempt of Test Run 15	Worked	
18	Cut piece of paper in half (5cm)	Did not work	Paper size should be controlled at 10 cm

Appendix X- Test Runs of Light Upon Earth's Rotation

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	Earth inflatable globe Smallest figurine(5cm in length) Thick string to hang Blu-tac	issues with blu-tac figurines not staying on Hard to hang	Put blu-tac on Earth first Place figurine on second Then hang Earth Hold in middle of room easier Best distance if 2.35m of flashlight from Earth
2	Smaller piece of string Hold in middle of room Spin slowly	Clearly see two halves of day and night	
3	Smaller sphere object (soccer ball) Create net out of string to hold ball	Light covered whole object	Soccer too small Size should be around 90cm in circumference
4	Bigger animals	Animal fell off	Too big, animals needs to be 5cm long and no more then one pound in weight Helps to wrap feet of figurine in blu-tac
5	Two figurines on opposite sides	Worked	
6	Re-attempt Test Run 5	Worked	
7	Re-attempt Test Run 5	Worked	
8	Extension with corks Three corks on same meridian of globe	Corks weighed down side so Earth tilted Shadows only visable in one location Person arm get in the way	Try standing higher up.
9	Extension with corks Stand on chair	Did not work Shadows only visable for very short period of time	Did not get results wanted

Conclusion: The experiment was extremely boring, and not interactive for students since it was discussion based. Also, it was very frustrating to construct and put together. The experiments also was not constructed of simple materials that would be easier for teachers to find and use. We decided after the self-testing to attempt to get suggestions to re-develop or change this experiment to make it fun, simple, and more hands-on.

Appendix Y- Test Runs of Paper Rolls

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	Two toilet rolls Placed about 10cm apart Drinking Straw	Did not work	Need to move rolls closer together
2	Two toilet rolls Placed about 5cm apart Drinking Straw	Did not work	Need to move rolls closer together
3	Same materials Placed about 2.5 cm apart Re-attempt of Test Run 2	Worked	Seemed too obvious of a distance, re-attempt at 5 cm
4		Worked Had to blow extremely hard	
5	Re-attempt of Test Run 2	Did not work	
6	Two Pringles can 5 cm apart Re-attempt of Test Run 6	Worked	
7		Did not work Cans too big	At this point the amount of time blowing into the straw not only was tiring but it also gave the person a headache and caused them to get dizzy. We chose to throw this idea out since it is showing the same concept of a much easier design the cuddling balloon.

Appendix Z- Test Runs of Cuddling Balloons

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	Regular balloons Small amount of water Plastic Hanger Red twine Placed in hanger openings Distance apart 15cm Length of string down: 15cm	Did not work too far apart	Bring balloons closer together
2	Same materials Distance apart 5cm	Worked Balloons not balanced	Add more water to balloons
3	Half filled balloons Length of string down 28cm Distance apart 10cm	Didn't work Too far apart	Bring closer together
4	Same materials Distance apart 5cm	Didn't work Balloons too heavy	Less water
5	No water in the balloons Distance apart: 5cm Length down: 22cm	Worked Balloons constantly flying all over the place	Must have some amount of water in balloons Distance between balloons needs to be close to 5 cm
6	Balloon deflated size filled completely with water Blow balloon to small size about .45cm circumference Distance apart: 5cm Length of string down: 20cm	Do not let the balloons expand with the water Worked	Balloons need to be small to have a proper proportion of water to size in it Length of the string down should be about 20-30cm
7	Re-attempt of Test Run 6	Worked	
8	Re-attempt of Test Run 6 Wire hanger	Worked	
9	Same balloon set-up Distance apart: 6cm Length of string down: 25cm	Worked	Wire hanger is much easier to use the plastic hanger Can easily tie balloon to it
10	Re-attempt of Test Run 10	Worked	
11	Re-attempt of Test Run 10 White string	Worked	
12	Same balloons and hanger Distance apart: 4.75cm Length of string down: 19cm	Worked	
13	Re-attempt of Test Run 12	Worked	
14	Re-attempt of Test Run 12	Worked	
15	Open-ended investigation Blow where balloons come together Try blowing from all areas except the middle	Balloons did not come together Need to come together on initial blow	Need to steady the balloons after each blow Ensure balloons are steady
16	Re-attempt of Test Run 15	Worked	
17	Re-attempt of Test Run 15 Extension	Worked	Type of string doesn't make a difference on experiment
18	Try to get four balloons to hit each other Team activity Blew straight through the balloons	Did not work Only front two came together	
19	Blew from side of hangers	Did not work Only front two came together	

Test Run	Set Up	Notes/Results	Conclusion/ Changes
20	Two people blow in the middle Opposite sides of each other	Did not work Neither came close to touching each other	
21	Two people blow in middle One person 90 degrees away from the other	Did not work Some touched Not all 4 at same time Mostly due to swaying and swinging of balloons	
22	Two people blow from same spot	Did not work Only front two touched	
23	Use straw to blow in between four balloons	Did not work Only front two touched again	Extension does not work Will keep as an extension since it will provoke discussion and scientific thinking Possibly students figure out a way we were unable to think of

Appendix AA- Test Runs of Spinners

For all testing the paper template spinner was used and dropped from Observation desk of Gallery

Test Run	Set Up	Notes/Results	Conclusion/ Changes
1	Wide Template One paper clip	Did not work	Thin template, two per sheet
2	One paper clip	Worked	
3	Re-attempt of Test Run 1	Worked	
4	Re-attempt of Test Run 1	Worked	
5	Add extra paper clips to base	Worked	
6	Re-attempt of Test Run 4	Travelled slightly faster	
7	Re-attempt of Test Run 4	Worked	
8	Triangle folds to flaps	Worked	
9	Re-attempt of Test Run 7	Worked	
10	Re-attempt of Test Run 8	Worked	
11	Box fold to flaps	Worked	
12	Re-attempt of Test Run 10	Worked	
13	Re-attempt of Test Run 10	Worked	
14	Roll base of spinner Add paper clips	Worked Landed upright	Challenge students to get spinner to land
15	Re-attempt of Test Run 13	Worked	
16	Re-attempt of Test Run 13	Worked	
17	Placed paper clips on flaps	Did not work Added weight to flaps	Paper clips can only be placed to the base of the spinner
18	Split the length of spinner in half	Worked Spun a lot faster	
19	Re-attempt of Test Run 17	Worked	
20	Re-attempt of Test Run 17	Worked	
21	Throw spinner in air	Worked	
22	Re-attempt of Test Run 20	Re-gained orientation and spun down	Extension to throw spinner in air
23	Re-attempt of Test Run 20	Worked	

Appendix BB- Resource Evaluation at Teacher and Staff Testing

Resource Evaluation Session Teachers and Staff

Aim of Session:

- To see the effectiveness of resource from a teacher's perspective
- To receive suggestions on improvements to the prototypes

Timing:

- 1:00-1:30: set-up stations for each resource
- 1:30-1:40: introduction of ourselves and of the other members of the session, and break members into groups
- 1:40-2:05: First Activity
 - Provide procedure for each station
 - One group at each station
 - Stations:
 - Balloon Rocket
 - Online Flight Interactive
- 2:05-2:30: Discussion
 - In-museum resources
 - Printed out version for each participant
- 2:30-2:55: Second Activity
 - Provide procedure for each station
 - One group at each station
 - Stations:
 - Circus Activity
 - Spinners
- 2:55-3:25: Discussion
 - Whole group discussion
 - Each group present ideas and suggestions on prototypes
 - Other groups provided extension
 - Present Light Upon Earth's Rotation
 - Need suggestions and recommendations
 - More interactive and hands on for students
 - Not as complicated and detailed materials for Earth
 - Important to have resource for Earth, Sun, and Moon
- 3:25-3:30: Say Thank You and if anyone has further suggestions or feedback feel free to contact or email us at anytime
- 3:30-4:30: Clean-up

Station Activities: Each station will be run by two team members

Provide paper to each group to take notes on each station while present for discussion at end.

Balloon Rocket- Jake Cabrera and Alyson Talbot

- Provide teacher notes
- Provide materials and have two courses set up
- Split group in half to race

Circus Activity- Jake Cabrera and Alyson Talbot

- Provide teacher notes
- Mini-Stations
 - Cuddling Balloons already constructed
 - Paper wing to be constructed
 - Air v. Bottle to be constructed
- See connection to flight

Spinners- Jon Tashman and Jon Zoll

- Provide teacher notes
- Display idea of picture procedure
- Template provided
- Rip and fold template, no scissors
- Done in stairwell outside the room

Online Flight Interactive- Jon Tashman and Jon Zoll

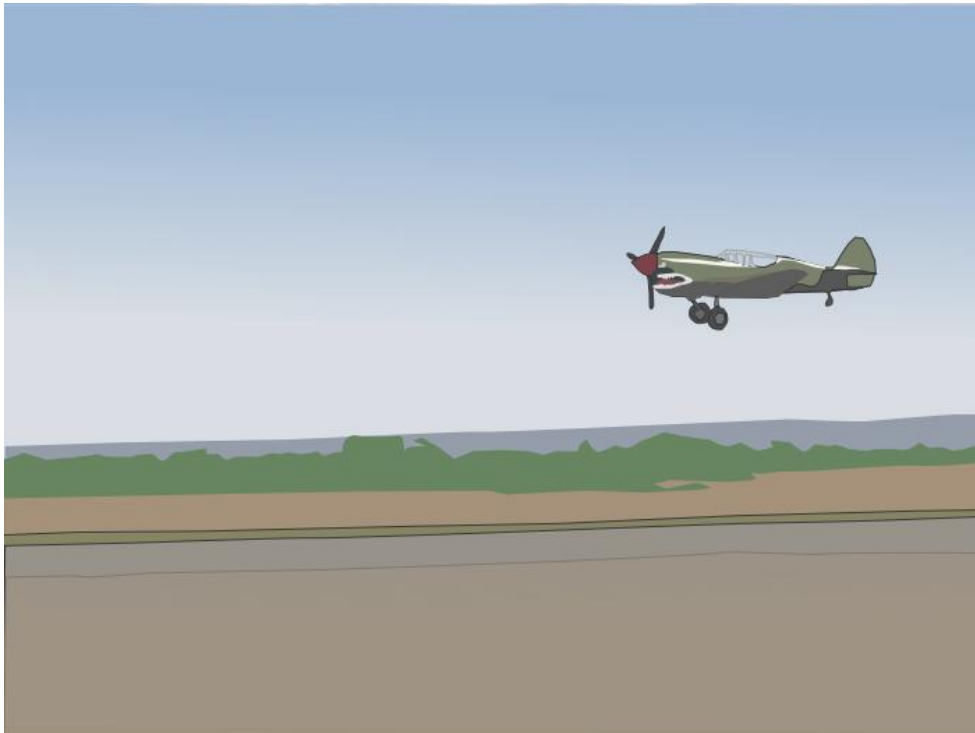
- Provide three laptops with game
- Guide through introduction, rules, and basic concept of game
- Allow them to play remaining levels of game

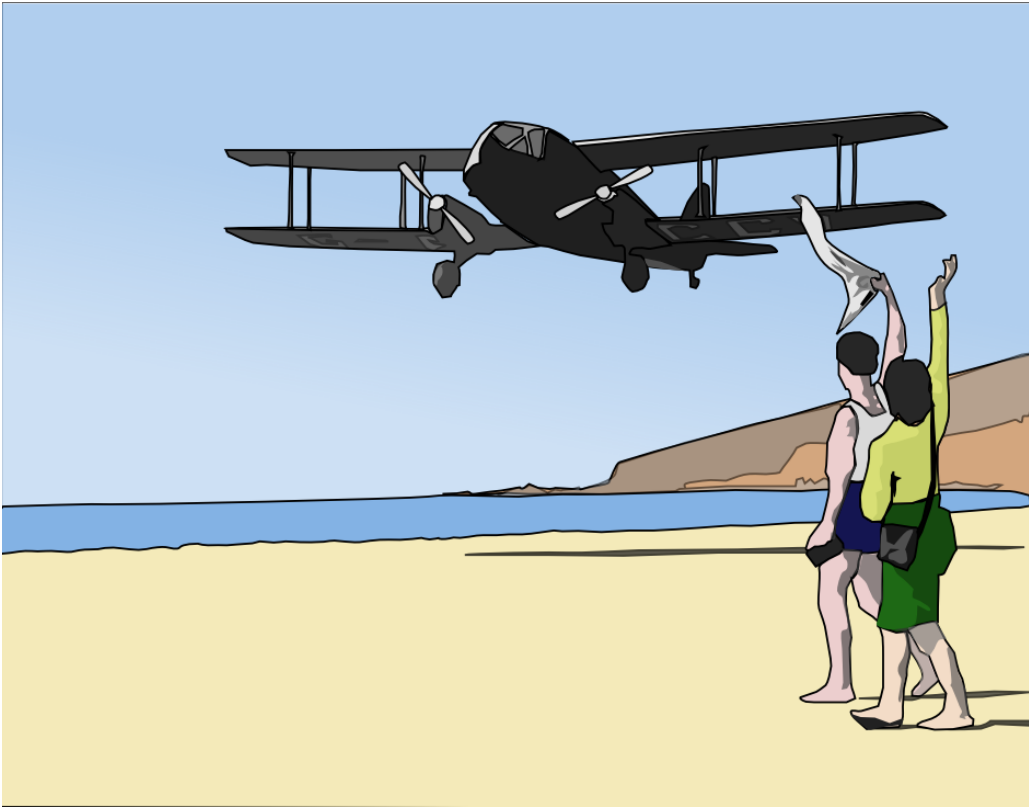
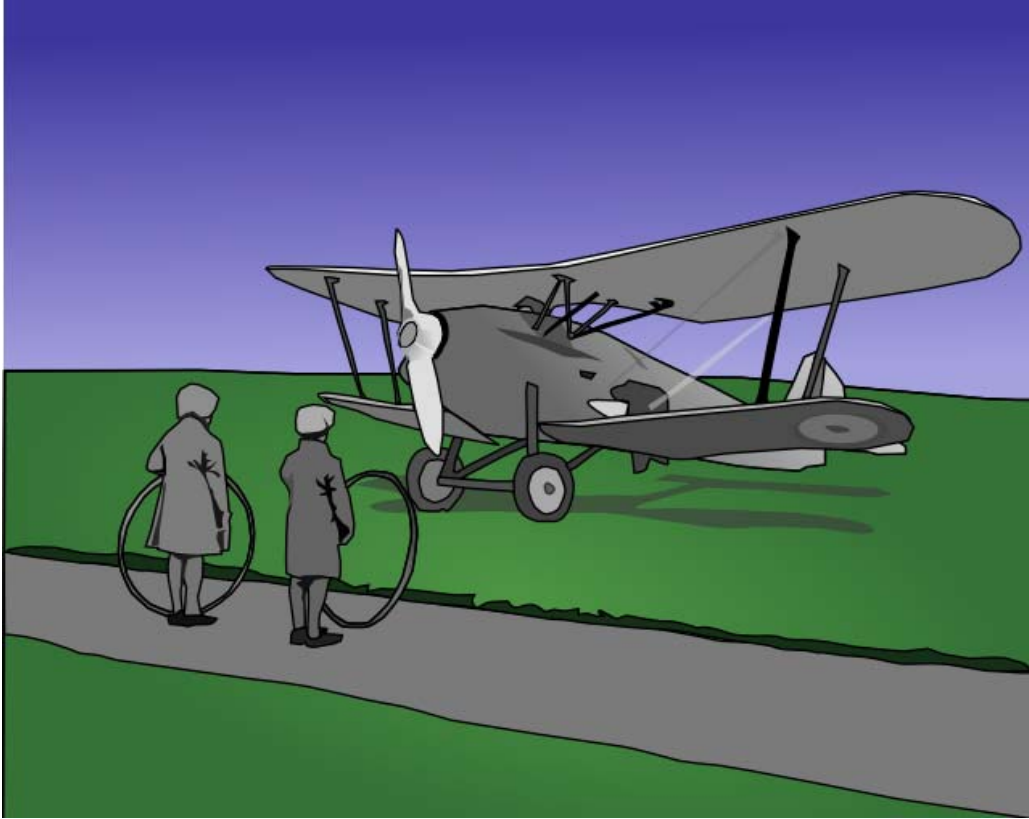
Appendix CC-Example of Level Ladder for Experiment on Smoking and its Effect on Birth Weight

Level	Additional guidance
3	<p>Considering Evidence With assistance, learners make a simple statement about the evidence. They may be able to make a conclusion from the evidence, but may not distinguish between the pattern and the evidence.</p> <p>Evaluating Evidence Learners should make a suggestion of how to improve the investigation, e.g. <i>ask more/the same amount of smoking mothers as non-smoking mothers.</i></p>
4	<p>Considering Evidence With assistance, learners describe the evidence. They may be able to state the pattern and state a conclusion from the evidence, distinguishing between the pattern and the evidence.</p> <p>Evaluating Evidence Learners should be able to justify at least one improvement suggestion.</p>
5	<p>Considering Evidence Learners describe the pattern, quantitatively where possible. They distinguish between the pattern and the evidence. A scientific reason must be offered for the evidence, e.g. <i>smoke contains chemicals (nicotine or carbon monoxide) which slows growth.</i></p> <p>Evaluating Evidence Learners should be able to justify their improvement suggestions, making reference to their confidence in the evidence, e.g. <i>different sample sizes, sample size too small, ask the whole of the year group instead. A larger sample is more reliable.</i></p>
6	<p>Considering Evidence As for Level 5, but the scientific reason for the evidence should be more detailed, e.g. <i>smoking lowers the amount of oxygen in the bloodstream, so less oxygen will get to the baby, so it will grow more slowly.</i></p> <p>Evaluating Evidence Learners should be able justify their improvement suggestions, making reference to their confidence in the evidence, e.g. <i>different sample sizes, sample size too small, ask the whole of the year group instead. A larger sample is more reliable.</i></p>

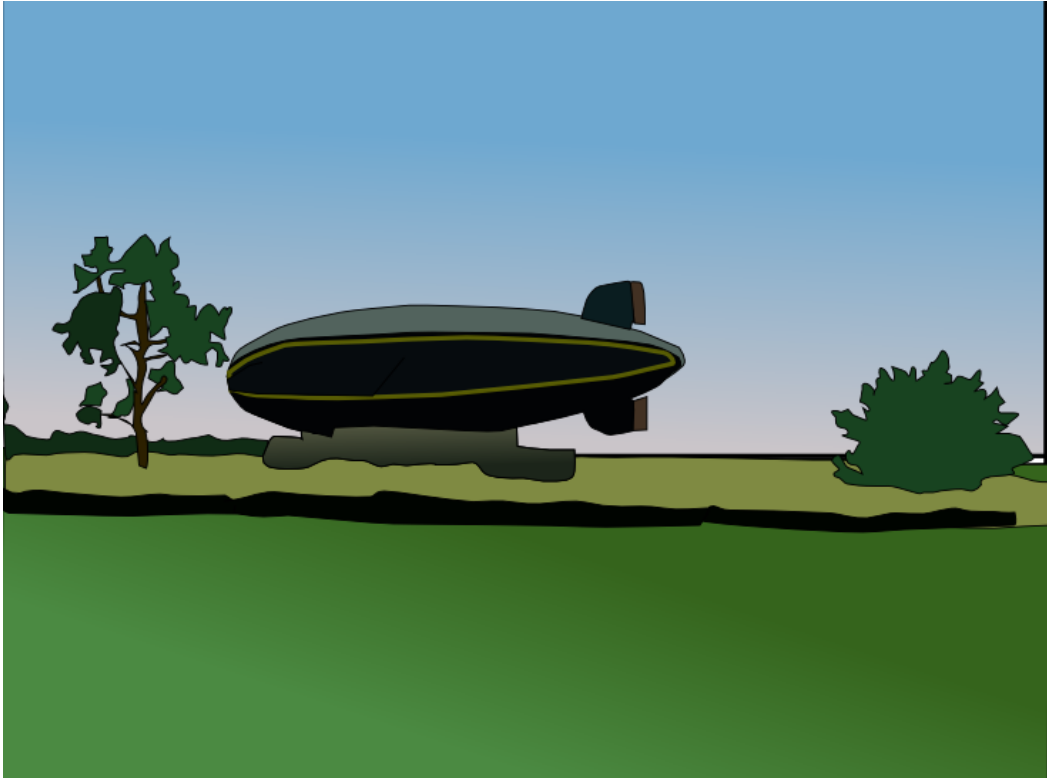
7	<p><i>As for Level 6, but should also consider:</i></p> <p>How many cigarettes the mother smoked per day.</p> <p>Whether the babies were boys or girls.</p> <p>Found out other factors that could effect birth weight, e.g. <i>alcohol drinking</i>.</p> <p>If babies were born prematurely or at full term.</p>
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Appendix DD- Flight Path Screenshots









Appendix EE-Light Upon Earth's Rotation

Light Upon Earth's Rotation

Educational Objective

To draw connections between the rotation of the Earth and the occurrence of night and day, seasons, and length of day and year, this is displayed in this experiment by the slow turning of the spherical object with a light source directly on it. The connections can be made from observing one object in a certain area and realizing it takes on full turn to return to its starting point and that is equal to a day.

Key Learning

- The importance of rotational movement of Earth on its on axis

Materials

- Sphere shaped object around 90cm in circumference (beach ball, globe, football etc)
- Direct light source (torch, slide or overhead projector)
- Blu tack (similar material)
- String
- Small figurines or other objects, (4.0-5.0cm in length and weigh no more than a pound)

Extension:

- Golf tees or corks

Procedure

- Attach a 30cm piece of string to the spherical object (that represents the Earth). If there is no clear place to attach string make a new for the object. (DIAGRAM WITH OWN INSTRUCTIONS)
- Attach the small figurine to the sphere shaped object with blu tack. Ensure the figurine is on there securely.
- Hold the sphere shaped object in the middle of the room.
- Shine the light source directly at the sphere shaped object from the side
- Slowly turn the Earth (Ask students which direction the Earth should spin, they should respond with to the right our counter clockwise)

- Attach another figurine anywhere on the sphere shaped object with blu-tack.
- Slowly turn the Earth again
- Observe how the light hits the figurines

Practicalities

The light source must be large enough to illuminate the whole Earth. If using an overhead projector you can cancel out the “extra” light by using a sheet of paper with a hole cut out of its center. Place this piece of paper over the light source.

When using the blu-tack to attach figurines it works best to first place it on the sphere shaped object and then attach the figurines to the sphere shaped object. You can also wrap the blu tack around the bottom of the figurine for a better hold.

Open-ended Investigation

If using a globe ask the students to place the figurines on a location where neither of the figurines will ever be in light or darkness at the same time. Also, ask the students to place the figurines in locations where one sees the sunset the other sees the sunrise at the same time.

If not using a globe, ask students to draw the continents and certain countries onto the sphere shaped object.

Discussion Ideas

- In what location does the sun rise and set?
 - The sunrises in the east and sets in the west.
- Would this change if the Earth rotated in the opposite direction?
 - The sun would then rise in the west and set in the east.
- Compare the location of where the sun sets with the two figurines?
 - Which one sees light first?
 - Can both be in light and darkness at the same time?
 - Or can only one be in light and the other be in darkness?
- Discuss why the Earth is split into time zones and why it is.
 - The Earth is split into time zones so that there is consistency with time all over the world. This way at 10pm in China it will be dark and when it is 10pm in the United Kingdom it will also be dark. Otherwise it could be light during normal hours in the United Kingdom, but in China it would be light during the times of 10pm to 5am for example. This compensates for the Earth’s rotation to allow all people throughout the world to experience the schedule.
- Discuss how long days are and why they are that long.

- The length of a day is 24 hours, and that is due to the fact it takes the Earth 24 hours to spin about its on axis.
- Does the length of day change based on location? At the equator or at either pole?
 - The day length is still technically a 24 hour day, but at the poles not as much daylight is observed, and at the equator there isn't as much darkness observed.
- What would occur if the Earth rotated faster or slower?
 - If the Earth rotated faster the day length would be shorter then the usual 24 hours, and if the Earth rotated slower the day would last longer then 24 hours.
 - Ask your students if they wished the Earth rotated faster or slower? What would they do with the extra or decreased amount of time?
- Discuss the importance of the Earth's rotation? What would occur if the Earth didn't rotate?
 - The importance of the Earth's rotation is that without it certain locations would be in constant sunlight and others would be in constant darkness. We do not know if life could exist in such a situation, but it would not be pleasant in either situation. The rotation allows life to exist in "normal" schedule and routine with day and night.

Extensions

- Attach a golf tee or cork to the Earth with blu tack at the location of your school. (latitude)
- Slowly turn the globe counter clockwise
- Observe the shadows made by the golf tee
- Attach three golf tees at different latitudes but along the same meridian longitude (place at the same point vertically)
 - One at the equator
 - One at your location
 - One near the either pole
- Have three students observe one of the golf tees
- Slowly spin the Earth
- Have students call out their golf tee (top, middle, bottom) as it crosses over the day-night boundary
- Observe the shadows

Discuss with the students the direction, size, and pattern of the shadows given off by the golf tees. Ask where the shortest shadow points. Compare it to the shadows given off by the previous figurines. Discuss the difference in day-night boundary and shadows depending on the position along the longitude. Also, you can take your classroom outside and ask for them to look at their own shadows and discuss those as well.

Links to Curriculum

- Earth, Sun, and Moon
 - Key Stage 2
- Geography

Links to Science Museum

- Space Gallery
 - Discuss the rotation of Earth and its importance to life and Space travel
 - Extend the idea of Earth's rotation with the Moon's rotation around the Earth and its effect