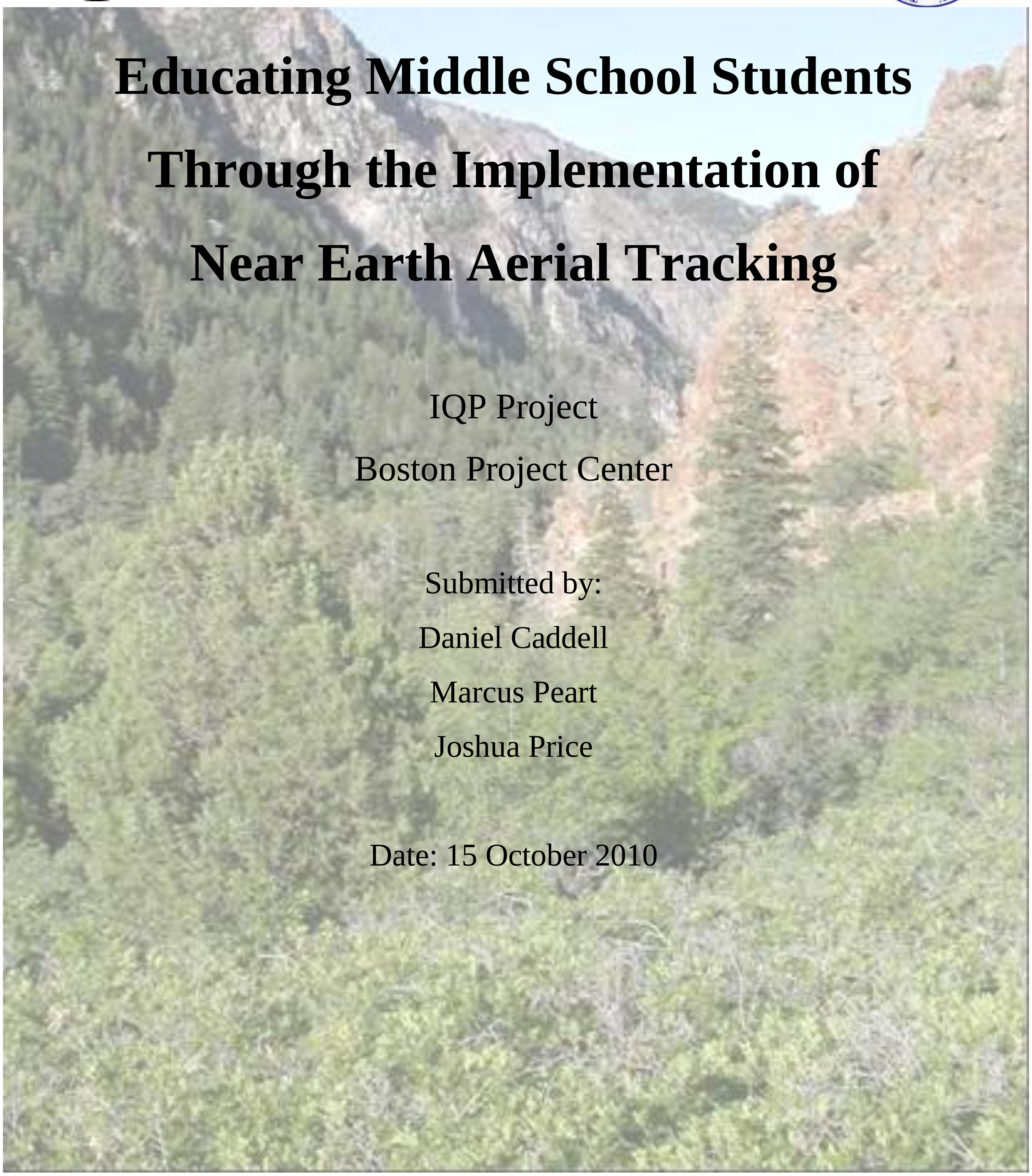

Educating Middle School Students Through the Implementation of Near Earth Aerial Tracking

IQP Project

Boston Project Center

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Abstract

This project describes the importance of Near Earth Aerial Tracking as an educative tool, and how its use may broaden students' interest in their local environment. The goal of this project was to use Near Earth Aerial Tracking to encourage students and professionals to collect data regarding the vegetative health of plant life in their communities. In order to achieve this goal, we achieved three objectives; we analyzed already existing programs, optimized our equipment and program, and designed an integrated curriculum for students. Two kits were designed as a result of this project. These kits help encourage the reinforcement of mathematics, science, engineering and technology.

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Chapter 2: Background-Integrative Methods in Educational Curriculum	*Marcus Peart*	*Joshua Price*
Chapter 2: Background- Measuring Environmental Impacts by Monitoring Vegetation	*Marcus Peart*	*Joshua Price*
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Executive Summary

Over the past few years, global climate change has developed into a significant issue that has affected the world's population. Many organizations are attempting to monitor climate change in their immediate areas but have had difficulty since the effects are not always obvious. While melting of the polar icecaps is an example of a highly noticeable effect of climate change, vegetative growth is much more delicate, capable of being affected by a change in temperature of only a few degrees Centigrade. By monitoring vegetation, it will be easier to understand the effects that climate change has on the local environment.

There has been a minimal amount of vegetative data measured and recorded in the Boston area. Organizations, including the Boston Museum of Science and the Blue Hill Observatory, have used techniques, such as MVHimage (Measuring Vegetation Health) systems and Picture Posts[1], to gather vegetative data. Despite these efforts, the data that have been accumulated thus far are not adequate. Picture posts can only monitor vegetation at the ground level. An alternative strategy is to implement Near Earth Aerial Tracking[2] so that vegetation can be observed on a much larger scale. With this method of image gathering, the MVHimage system will be much more of a useful tool for analyzing vegetative health. Since the organizations that have gathered data so far have a limited number of staff members, it is essential to involve more people in the process. By involving middle school students with Near Earth Aerial Tracking, the existing programs will be able to perform at a higher capacity, while

[1] Picture Posts are wooden posts in selected areas with each of the cardinal directions labeled, such that any interested person may take a 360 degree panorama of images
[2] Low altitude photography taken from kites, balloons, or remote controlled planes or helicopters

creating an outlet to teach students about climate change and its effects, in addition to reinforcing STEM[3].

The goal of this project was to use Kite and Balloon Aerial Photography to create a curriculum for 5th through 9th grade students, enabling the students to collect data on the vegetation in the area, and teaching them about the effects of climate change while reinforcing previously learned mathematics and science material. The kits were designed to be as easy to use as possible for both the students and teachers. Therefore, schools could be self-sufficient and not require the aid of staff from the Blue Hill Observatory. We wanted to create a learning experience for the students that can take place both inside and outside of the classroom. Our curriculum teaches students about geometry, algebra, life and earth science, and different aspects of engineering, and encourages students to improve their awareness of the effects of climate change. By collecting photos and observing their surroundings, the students, alongside the Blue Hill Observatory, will create a system of data collection and storage that is able to be used and expanded upon over time.

Our group had created a set of objectives to achieve our goal. The first objective was to identify the types and costs of kites and balloons that could be used for such applications in the schools. In order to complete this, we explored the options that are already being used by the Blue Hill Observatory within their programs, as well as options that had yet to be considered. The second objective was to create a kit for Aerial Photography that is both cost-effective and appealing to the students. This required us to explore the demographics among the towns we were involved in, including the racial and financial percentages of the population. The final objective was to design a curriculum for the 5th to 9th grade students that reinforces principles in

[3] Science, Technology, Engineering, Mathematics

academics, such as geometry and earth sciences, and educates the students about the health of the environment.

We utilized various methodologies to enable us to achieve our objectives. In order to achieve our first objective, we analyzed the various types of kites and balloons that are currently on the market. Certain constraints, including wind resistance and the lifting power of the kites and balloons were noted. Due to the varying conditions at the location of the schools where students will be flying the kites and balloons, a range of designs were required. We then had to verify which kites and balloons were able to handle the complex control rigs and the cameras used in aerial photography. The second objective required us to perform a cost-benefit analysis of the kit design. We designed separate kits that could either be purchased or rented by the schools. We had to examine the costs of the individual components (kite, balloon, camera and rig) that make up the kit. After designing the kit, we aimed to create a curriculum that goes along with the existing Massachusetts Curriculum Frameworks. Our group examined previous interactive curricula that have been used in schools, in order to determine how to optimize the effect our program would impact the classroom. In order to minimize damages to the equipment and produce accurate results, our team visited each school and provided a demonstration to both the teachers and students.

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Chapter 1: Introduction

In the last decade, global climate change has become a worldwide concern. The steady increase in average global temperature has led to noticeable changes in biological ecosystems. There is a general dearth of information regarding the effects of these changes. Due to this lack of information, it has been difficult to gauge the human effects on the environment. Near Earth Aerial Tracking (NEAT), aerial photography taken from low altitudes may be capable of providing the data that has been unavailable. Near Earth Aerial Tracking, which could include the use of either kites or balloons to lift the camera, could prove to be a valuable resource in the classroom. The availability of aerial photography in schools would not only allow teachers to institute an interactive curriculum, which would have the potential to span many strands of the educational framework, but allow interested students to monitor vegetative health. This method may serve to keep students interested in their surroundings, learning about the potential impact of global climate change on local ecosystems.

To date, schools within the greater Boston area follow the Massachusetts Curriculum Frameworks. According to the Science and Technology/Engineering section of these frameworks, students will learn about plant reactions to their environment in the 3rd-5th grades, and then learn about the diversity within a species due to environmental factors in the 6th-8th grades (Massachusetts Department of Education, 2006). While the absence of aerial photography in the classroom is not currently a detriment to the math and science programs of the local school systems, its introduction to these programs would present teachers with the option of creating a more engrossing lesson plan, getting students involved in their local environment, while still maintaining the goals set forth by the Massachusetts Curriculum Frameworks. There is a deficiency of knowledge regarding the vegetative health within the Boston area. Therefore, the use of aerial photography allows for the collection of valuable data, which could lead to a greater understanding of the human and environmental effects on Boston's vegetation.

In the past, much of the collection of vegetative data came through the MVHimage (Measuring Vegetation Health) program. This system is a database that makes use of light detection methods as well as analysis of color digital images and remote sensing in order to monitor the health of vegetation in the area. This is used side by side with Picture Posts[4], a tool that was created to allow for standardized photos of any given setting. The MVHimage program, which has been utilized by organizations such as the Blue Hill Observatory and the Boston Museum of Science, was created by NASA to give students a hands-on experience, teaching them the importance of monitoring the environment and its health (Measuring Vegetation Health, 2006). The MVHimage program at the Blue Hill Observatory has been limited to Picture Posts in designated areas. The MVHimage program, used in conjunction with Picture Posts, has been used to track vegetation health. In recent years, the program has taken to the skies via Kite Aerial Photography. This has been implemented with students through the use of "Frustrationless Flyer" kites, sled kites that have been specifically designed so that young students may construct them in a very short amount of time. This model of kite is small and not very efficient, needing up to ten or more kites strung together to have enough power to lift camera equipment into the sky.

Due to the costs to buy and operate aerial photography equipment, it has been difficult to spread this program throughout the Boston area. Most schools cannot afford to purchase and operate this equipment, as some of the equipment, such as the different models of kites in addition to the camera rigs and equipment can cost upwards of a combined $500-800. The Blue

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[4] Picture Posts are wooden posts in selected areas with each of the cardinal directions labeled, such that any interested person may take a 360 degree panorama of images

Hill Observatory is researching ways in which aerial photography equipment can become readily available for schools. In order to do so, the Blue Hill Observatory must collect data and information about different types of camera equipment, kites, and balloons, as well as experiment with different ways in which they can be combined to improve functionality. On September 9, 2010, Don McCasland, Program Director at the Blue Hill Observatory, sent out a mailing to teachers of local schools, introducing the availability of NEAT to schools (See Appendix C). Since then, multiple schools, including Braintree High School, Galvin Middle School, and Milton Academy, have expressed interest in working with the Blue Hill Observatory to use this equipment for NEAT. Schools were given the option to either buy or rent the necessary equipment, thus allowing schools to affordably participate in the Measuring Vegetation Health program, as well as expand their curriculum.

The aim of this project was to design a curriculum that would reinforce students' knowledge of mathematics and the sciences, while additionally providing a system by which vegetative growth in the greater Boston area can be monitored over time. Our group, in collaboration with the Blue Hill Observatory, had laid out three main objectives in order to achieve this aim. We designed the educational kits in such a way to minimize their cost, making them affordable for schools to either buy or rent. We then designed an interactive curriculum for students between grades 5-9 around the kits. The curriculum was designed in such a way that enabled the students to collect data about their local environment. After developing the curriculum for the students, our team traveled to the individual schools in the area to teach the educators and the students how to use the equipment to fit their needs. Once the curriculum and kit equipment were finalized, students became able to collect data as part of an interactive learning experience. The students will be able to track environmental changes, allowing them to monitor the effects of human activities on vegetation.

Chapter 2: Background

Background research was conducted in order to develop objectives that will help us achieve our goal. This chapter will cover four main topics:

1. Vegetative Monitoring
2. Demographics
3. Education Curricula
4. Aerial Photography

Vegetative monitoring is necessary for collecting data and recording observations. This process will help communities and government organizations maintain or improve environmental conditions of specified areas. Information about the demographics within areas of interest allows the team to get a better understanding as to what may be financially attainable for school districts. An educational curriculum is necessary to enable students to collect vegetative data while also becoming more familiar with its subject matter. Kite and balloon aerial photography are means with which to monitor vegetative growth. The pictures are taken at a lower altitude than satellite images, giving the photographer an opportunity to observe finer details. Aerial photography is an alternative learning experience that takes students outdoors to learn about many concepts such as weather, geometry, as well as other mathematical and scientific principles.

Measuring Environmental Impacts by Monitoring Vegetation

There is not a sufficient amount of vegetative data in the Boston area. This is an important issue because the public needs to be more aware of the effects that human actions and natural events have on their environment. Vegetation monitoring is an important practice that measures changes or present conditions of resources through observation and collection of data. It is vital because it helps identify invasive species that might be harmful to humans, other animals, plant species or entire ecosystems. Measuring vegetation also helps to uncover the effects on plants that may have resulted from climate change. Since vegetation is constantly changing over time, it is necessary to monitor specific areas in order to understand if the changes bring any harm to the surrounding elements. Vegetative monitoring is also necessary for the reason that agencies can maintain long-term establishments such as parks and wildlife sanctuaries. Lovett (2007) explains that vegetative monitoring will continue to have an impact because it can create a data system that can grow to study or undertake future environmental issues. He also explained that a regulated area can be mapped or monitored to determine the best cost effective approach for maintaining the area.

Elzinga (1998) created a handbook that has been used or cited by many monitoring experts in its field. The handbook consisted of a set of steps for monitoring vegetation, which included completing background tasks, developing objectives, implementing monitoring and reporting and using the results. In order to complete the background tasks, Elzinga states that the priority species that would be monitored were identified by reviewing existing records or data on the plants. Additionally, she states that project groups should examine the range of monitoring equipment so that they will not be limited in their observations. The groups would also have to determine the extent of data collected. For example, Elzinga explains how some monitoring requires only quantitative data, such as statistics and data tables that are collected and compiled through sampling, while others require qualitative data such as observations on the condition of an environment and its various ecosystems. In many cases, a combination of both types is necessary. For instance, collecting data on the condition of an area might lead to sampling plants in certain parts of the same area.

Elzinga (1998) notes important techniques in the handbook, such as models. An ecological model by the use of computer simulations or math equations could specify how species interact in an environment. She also states that groups should select indicators to measure the success of the species or monitor possible threats. Another objective for monitoring deals with managing a time frame. For instance, if minimal changes are observed over a certain time, then the time frame might need to be adjusted to either prove that change has not happened or to allow enough time to produce a significant result.

Elzinga (1998) claimed that field data should be collected to assess the findings from the vegetation monitoring. After analyzing the data, certain conclusions could be drawn to explain how to maintain the condition or solve the problem of the vegetation.

Such methods for monitoring combine multiple types of data. For example, according to Elzinga (1998), qualitative monitoring of vegetation is conducted by identifying and determining a set of techniques which include a presence and absence approach, estimations of populations and an analysis of the condition of a site. In the presence and absence approach, observers would just monitor if a species still inhabits an area. Observers could also qualitatively monitor vegetation by estimating the size and condition of the population. Also, the site or area would be monitored to examine any disturbances like an invasion by an exotic species of plant. However, this isn't always the best approach to monitoring the vegetation, as the presence of a specific plant does not inherently mean that the species is healthy. Quantitative monitoring, which includes sampling the plants, could also be an effective method because it can allow for analyzing of the vegetative health by means of physical and experimental observations. In addition, a census could be used to count species or individual characteristics, such as the stem or the number of seeds produced by a plant.

Elzinga (1998) and Lovett (2007) and many other field experts stated the various types of equipment. EDMs (Electronic Distance Measurers) along with GPS (Global Positioning Systems) can be used to create boundary mapping. EDMs use sound waves and invisible light to measure distances. They can be used to measure long distances or boundaries of vegetation. GPS acquires data from satellites to track a specific location on the ground. It can be used to map large plants such as trees and cacti. It can also map the boundaries of plant populations, which is useful when an observer wants to monitor a certain species. Picture Posts, in relation to other ground-positioned photo points, have been productive in highlighting trends in vegetation. Furthermore, aerial photography captured from kites and hot air balloons have been applied for vegetation monitoring. Aerial photography uses cameras to capture detailed images of vegetation and landscapes.

Monitoring vegetation could become a very useful tool if it was included in school curriculum. The integration of vegetative monitoring into school curriculum would allow students to explore their environment in order to learn more about local plant species. This integration could also allow students to work alongside local organizations, such as the Blue Hill Observatory, to create a database with which the health of ecosystems and specific plant species can be tracked over time. Additionally, the students could use their data to learn to understand the interactions between the climate and the local environment. The monitoring of vegetation is a very beneficial tool and should be included into school curriculums in some form.

Integrative Methods in Educational Curriculum

The creation of a curriculum, for 5^{th} to 9^{th} grade students, implementing aerial photography to measure vegetation, is important because it will allow the students to observe and collect data, which will educate them about their environment and the effects of climate change. In order to engage the students in the topic or subject matter, the curriculum must be well designed to meet the students' needs and their level of education. There are many approaches and techniques that can be developed and applied for an educational curriculum.

Current learning methods for educating middle school students do not focus on creating activities that help to give students roles in their areas. Service learning is an educational method that connects academic learning in middle school with outdoor projects and activities in the community (Schukar, 1997). This approach is very rewarding because it allows the students to be active in their learning while also increasing their awareness of the community. Techniques from service learning can be applied to our project because it would allow middle school students to work away from textbooks and classrooms while understanding how environmental changes affect the vegetation in their communities. The curriculum that we design would also allow students to present their findings on the vegetative health to councils and organizations in order to improve the environmental actions of the community. The students would be serving their community while also participating in an engaging educational experience. This method is also helpful because it would allow students to take responsibility for their own understanding of a subject. Schukar emphasizes that such an approach can help improve the relationship between the teacher and the students. Billig (2000) mentions that service learning methods have helped improve the students' self-esteem and behavior.

Middle school curriculum could be more effective in helping the students develop useful problem-solving skills. More real-world concerns need to be introduced to the students, so that they can take responsibility for their own analysis and conclusions of topics. Problem-based learning is a solution to this problem. It is another method where students are able to work as individuals or in groups to address challenging problems that they can resolve through reasoning (Koszalka, 2002). The KaAMS (Kids as Airborne Mission Scientists) project is one example of this approach. Students were instructed to solve specific problems that related to data that were collected by NASA. According to Koszalka, problem-based learning has five stages, which include introducing the students to the problem, allowing the students to make a plan to solve the problem, collecting important data on the problem, analyzing results and presenting and sharing the solution to the class and teacher. The middle school students who participated in this program were able to incorporate data that were taken from real NASA missions into their experimental projects and learned about how to address important issues such as lava flows and coral reef protection. In this approach, the teacher facilitated the work done by the middle school students instead of just instructing them on how to solve every problem. Our group could utilize similar methods because the curriculum should encourage the middle school students to think independently while also maintaining the standard of learning.

KidSat was another NASA funded program that involved middle school students with photography from space shuttle missions (Stork, 1999). The program, another example of problem-based learning, pushed students to think outside of their formal academic education to solve real problems. KidSat was also helpful because it designed computer modules, which allowed students to acquire or improve technical skills for research and interactive activities. Stork emphasized that the modules can be used for multiple subjects since they provide detailed photography of the Earth. From this program and its use of modules, Stork also observed that the students enjoyed targeting images of Earth, but more importantly, their pre and post-testing results showed that they improved their quantitative, writing and verbal skills.

These programs are relevant to our project because they encourage the middle school students to create their own solutions for the assignments and allow them to become better skilled at working with maps.

MOSS (Mapping Our School Site) and CITYgreen are two GIS-integrated curricula that originated from North Carolina State University (Hagevik, 2003). According to Hagevik (2003), these units include four diverse levels which include structured inquiry, guided inquiry, student directed inquiry and research inquiry. Structured inquiry provides students with helpful evidence to perform basic skills such as measuring or using scientific equipment for experiments. In guided inquiry, teachers choose the scope of the topic, but students collaborate with the teachers to plan methods on examining and concluding the assignment. Student directed inquiry and research inquiry are very similar. They both allow students to have full control of their assignments, but there is less guidance from the teacher in research inquiry.

These units allow teachers to introduce ideas to different grades based on their level of independence and scientific knowledge. The two programs are beneficial to middle school students because they display physical evidence of environmental issues that surround their school. They also educate the students about using new technologies like GIS, which can monitor vegetation and other resources that are found in ecosystems. Hagevik (2003) mentions that the CITYgreen unit is structured so that students solve problems from predetermined models, whereas the MOSS unit guides students to direct their own learning. In either case, the students were given a great opportunity to improve their awareness of the current condition of their surroundings. Middle school students are going be using the curriculum we design to take pictures using aerial photography to measure the vegetative health and discuss human impact on the environment.

These methods provide a broad range of learning techniques and activities. They are valuable because they review educational methods for middle school students that have worked in the past. Our group will use these tools to construct engaging lessons or activities that can be incorporated into the middle school curriculum. They will also be helpful because such lessons for aerial photography could be performed both in and out of the classroom. However, in order for our group to create a curriculum for students in the Boston area, we must focus especially on the learning standards in Massachusetts for middle and high school students.

State Education Standards

Massachusetts Department of Education reported specific learning standards for middle school students. The state organization provides standards for classes such as earth and space science, life science and mathematics, which we will use in developing the curriculum for our project.

According to the Massachusetts Department of Education (2006), the earth and space science class is designed to introduce middle school students to using satellite images and contour maps to uncover properties of geologic materials. It also recognizes that students, at this level of education, should perform direct and indirect observation to understand the phenomena that occur in nature. Middle school students should be able to describe quantitative changes by reading maps and charts. They must learn how to use changed and controlled variables in experiments to produce accurate results. Lab safety is addressed due to the increased participation in experiments. Middle school students also use important pieces of equipment such as a chronometer to measure time and record plots to indicate patterns of growth or decline patterns.

The Massachusetts Department of Education (2006) provides effective learning standards for life science, which consist of identifying biodiversity and the relations among species and observing changes in ecosystems over time. For example, students begin to comprehend how some species became extinct due to human action, such as habitat destruction and pollution. Another standard that teachers establish for students is the effects of symbiotic relationships in which one species either benefits, harms, or has no effect on another species.

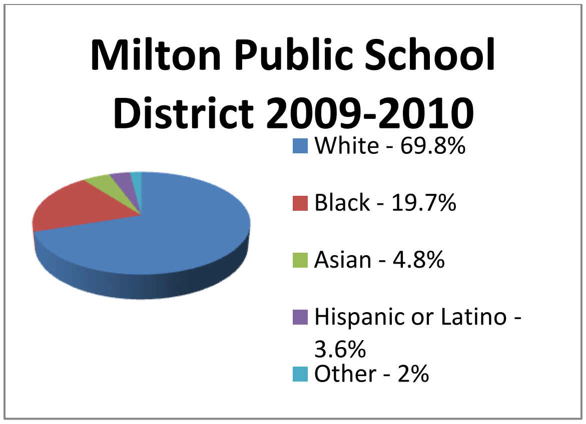
The Massachusetts Department of Education (2004) also includes standards for mathematical education that will help middle school students to measure data, such as plant variations. Students are challenged with implementing functions into real world applications. For instance, they can interpret linear and nonlinear patterns from graphs and by using proven equations or models, can calculate estimations or solutions. Other important topics include ratios, statistics and probability. Middle school students can compare averages or limits in an experiment. They can also use data analysis to make predictions that they can compare to actual outcomes.

A curriculum that implements aerial photography for middle school students would be a better alternative to current science curricula because it emphasizes on relating the local environmental threats directly to the students and allowing them to help resolve the conditions of the community. Furthermore, it also provides principles, such as geometry, mathematics, earth and life science, which will foster their education and ease their transition into high school. Aerial photography will allow the students to measure vegetation and make a difference in their community by providing the monitoring data. It has a significant background which includes many different designs and methods for observing plant vegetation.

Demographics

The demographics of the schools in the Boston area are important to our analysis in order to create the aerial photography kits. Our kits are adjusted according for each district, depending on the results of our demographics study. Public versus private school is another issue that affects the construction of the kits. Three specific regions of interest are the districts of Braintree, Canton and Milton. These three districts have diverse student bodies. As statewide student and teacher populations have decreased throughout Massachusetts, these three districts have continued to grow.

Diversity in Milton is on par with state levels with the exception that there is a much larger African-American population (19.7 percent in Milton versus 8.2 percent statewide) than that of Hispanic and Latinos (3.6 percent in Milton versus 14.8 percent statewide). Milton, however, has an increasing population of students from low-income households. Using the No Child Left Behind (NCLB) records that districts are required to keep, it is apparent that the low-income population has been growing steadily in the past few years from 10.7 percent in 2007-2008 up to 14.9 percent for the 2009-2010 school year. Despite this growth, this percentage is still well below the overall state's percentage of 32.9 percent, which has grown steadily from 29.5 percent in 2007-2008. Milton's student to teacher ratio of 13.7:1 trails State's ratio 15.3:1. Of the three districts we are interested in, Milton's student to teacher ratio was the highest.



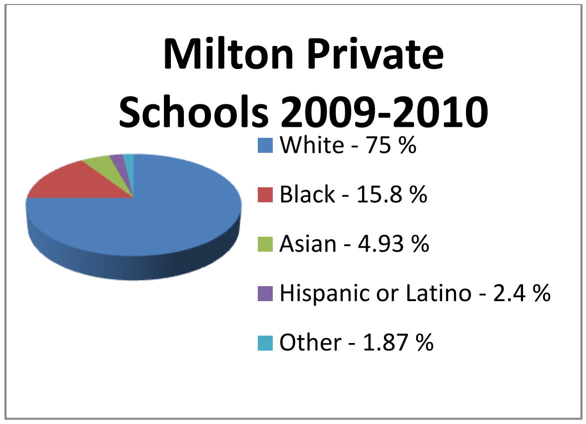
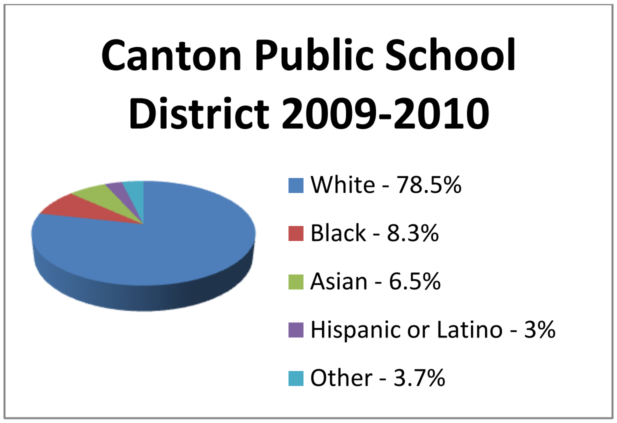


Figure 1. Public and Private School demographics within the Milton School District.

Source: Adapted from NCLB Records and Privateschoolreview.com

From this data, we determined that the Milton public schools have significantly more diversity than their private schools. The percentage of African American private school students was smaller, as well as the percentage of Hispanic private students, when compared to their respective public school data. This data conforms to the notion that private schools are less diverse simply because of the socio-economic situation that faces minorities. Additionally, the student to teacher ratio in Milton Private Schools is 10.667:1, far smaller than that of the public schools.

In Canton, today's student population is primarily Caucasian, with the white students making up 78.5 percent of the student body. This value has stayed consistent since the 2005-2006 school year, but has decreased over the past few years from 80.6 percent. Canton has lower diversity rates district wide with a white population of 79 percent when compared to statewide percentages of 69.1 percent. The percentage of low-income students had grown over the years with a peak value of 11.2 percent in the 2007-2008 school year. That trend has reversed in recent years, as the value has been reduced to 9.1 percent. This is the lowest rate amongst the three districts we are investigating. Additionally, Canton has the lowest student to teacher ratio of these three districts, at 13.4:1.



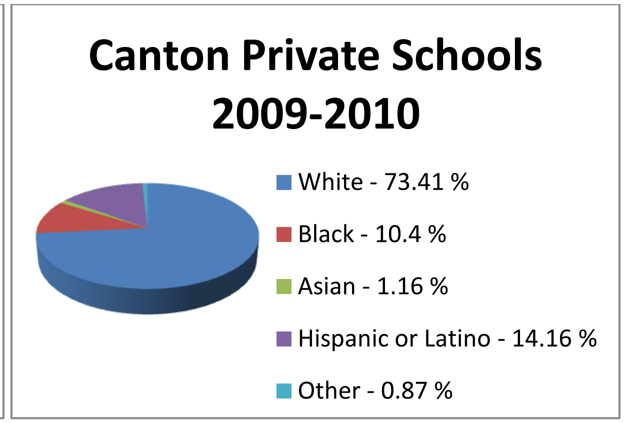


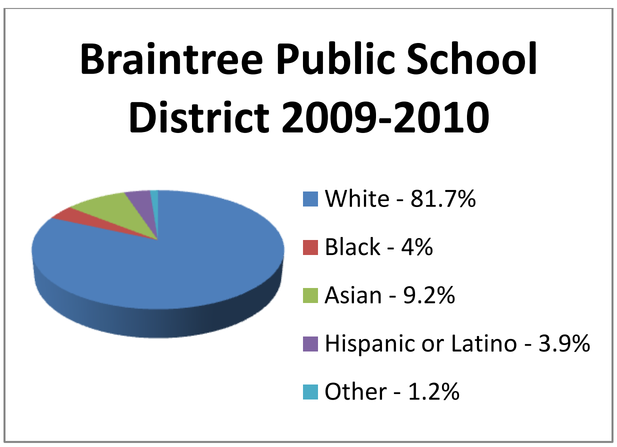
Figure 2. Public and Private School demographics within the Canton School District.

Source: Adapted from NCLB Records and Privateschoolreview.com

From this data, it can be seen that the percentage of diverse students is slightly larger in private schools than in public schools. The percentage of Hispanic students is significantly higher in private schools, which is the opposite of what is usually expected of most private schools. This seems inexplicable, as the total Hispanic population of Canton is only 296 persons, or 1.4 percent of Canton's total population. Upon analyzing the private school data for Canton schools, however, this data is easily explainable. Of the three private schools within the Canton school district, two of the schools are special education schools, the Judge Rotenberg Education Center and the Clark School East. The Judge Rotenberg Education Center has a student body of only 89 students, with 21.34 percent of the population being Hispanic, and 39.32 percent of the population being African American. The Clark School East has a student body of only thirteen students, with all thirteen being Caucasian. The final private school within the district is the St. John the Evangelist School, which is comprised of 12.29 percent Hispanic students. While this percentage is still high, this is due to the fact that Catholic schools historically attract a larger quantity of Caucasian and Hispanic families. Therefore, we can conclude that the increased diversity within Canton is a byproduct of the nature of its schools.

The student to teacher ratios are the closest in Canton between the private and public schools, with the ratio for private schools being 11.3:1, compared to the public school ratio of 13.4:1.

The diversity rate in Braintree is lower than state levels, at 18.3 percent, as opposed to the statewide rate of 30.9 percent. In Braintree, the diversity is increasing at a faster rate than in the rest of the state, up by 2.9 percent since 2007-2008 in Braintree, compared to the state's increase by 1.7 percent. The percentage of Low-Income students in Braintree has steadily increased to 13.6 percent this year from 11.3 percent in 2007-2008.



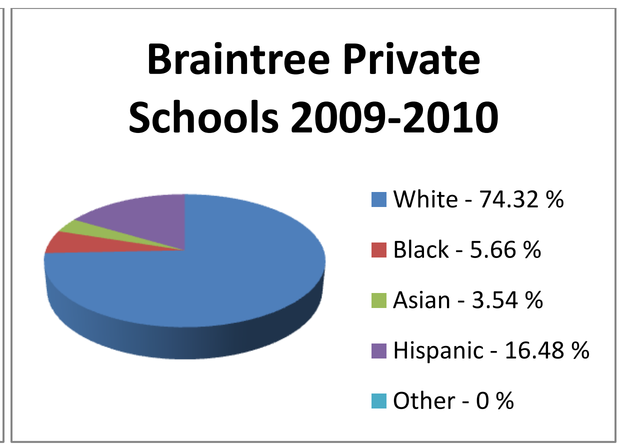


Figure 3. Public and Private School demographics within the Braintree School District.

Source: Adapted from NCLB Records and Privateschoolreview.com

From this data, it is shown that the percentage of diverse students is significantly larger in private schools. Once again, Hispanic students make up the majority of the diverse private students, a percentage that is 4 times larger than that in the public school system. As with the Canton School District, this may again be explained by analyzing the private schools within the district. There are six private schools within Braintree: Archbishop Williams High School, the

Cardinal Cushing Center, the Pilgrim Center, Thayer Academy, St. Francis of Assisi, and South Shore School. Of these, the schools with an abnormally high Hispanic population were the Pilgrim Center (13.51 percent) and St. Francis of Assisi (92.09 percent). The Pilgrim Center has a student body of only 37 students, whereas St. Francis of Assisi has a student body of 253 students. The size of the Hispanic student body in St. Francis of Assisi singlehandedly overwhelms the demographics of Archbishop Williams High, the Cardinal Cushing Center, Thayer Academy, and South Shore school, at 3.06, 3.44, 0.92, and 4.34 percent respectively. Both schools are Catholic schools, which as was previously stated, often attract larger populations of Caucasian and Hispanic students.

Aerial Photography

Aerial Photography is a means to capture low altitude photographs. This is a useful application when ground level photographs do not give a full representation of the area, while having a complete top view from an airplane does not show the same picture (Gentles, 2003). Aerial photography was first experimented by Gaspard-Félix Tournachon. His first successful flight was attempted from a hot air balloon, in 1858, over Paris, France (Baumann, 2001). Aerial photography encompasses a multitude of technologies for lifting a camera such as aircraft, helicopters, balloons, blimps/zeppelins, rockets, kites, poles and parachutes. Our team focused primarily on kite and balloon aerial photography.

Kite Aerial Photography

Kite Aerial Photography is made up of two primary components–the camera that is taking the pictures, and the kite itself. It is a relatively inexpensive and quick method to take aerial photographs, and given the correct resources, is highly effective. The costs involved with Kite Aerial Photography vary drastically depending upon the quality of photograph that is desired. To minimize costs one could attach a disposable camera to a kite and set the camera to take pictures on a timer. This is the type of method that would work well for hobbyists. Researchers, however, expect a higher quality image, and would invest in a more complex aerial system to support higher quality equipment. The downside of such materials is that the camera and rigs may be much heavier. Such systems may require multiple kites to lift the heavier loads.

Due to the potentially varying wind conditions, the operator of the KAP equipment must use different types of kites. Generally the most commonly used kites for general purpose Kite Aerial Photography would be the parafoil, rokkaku, delta and sled styles (Benton, 2001). These kites are able to lift relatively heavy loads of a couple pounds, making them very versatile. In particular, the rokkaku and delta kites are able to fly at higher angles, which are convenient for tight air spaces (Hunt, 2006). A high angle of flight is also beneficial because such conditions generate much more lift. The helikite is a more modern design which is able to fly in a wider variety of wind conditions ranging from high wind to no wind at all (Allsopp Helikites Limited). This is an added bonus for researchers who need to collect data regardless of weather conditions in the surrounding environment. However, this comes with a high price tag, with the lightest and cheapest models costing almost $130.

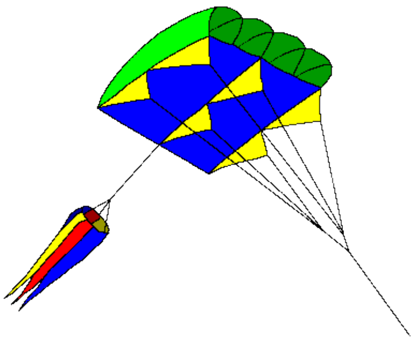


Figure 4. Parafoil, an illustration of a parafoil kite in flight with a drogue, or tail, for stability.

Source: (Le Riche, Philip. (2008) Retrieved 2010, March 30 from http://www.blueskylark.org/zoo/single/paraf/index.html)

The parafoil kite, as well as its variant called a flow form, is a type of kite called a soft kite. Soft kites do not require spars, or spreader bars that create a sturdy body for rigid kites. Soft kites have large cells that inflate the kite to a wing-like shape when they catch the wind (Aber & Aber, 2008; Le Riche, 2008; Hunt, 2006). Parafoil kites as well as flow forms can lift heavier weights than other types of kites and can be flown in a wide variety of wind speeds. When dealing with wind speed it is important to recognize that the wind will constantly be changing in strength due to gusts and lulls as well as from turbulence caused by ones immediate surroundings. The Beaufort scale is a simplified system that matches wind speed ranges to specific Beaufort values ranging from 0-12. These values describe winds from calm all the way to hurricane force. This is a useful tool since these categories can determine which kites can fly and lift certain types of rigs. Typical values for both the parafoil and flow form to be able to fly are from 1-4 Bft, or 3-20 mph, which give them the versatility to stay in the air regardless of changing wind speeds. A standard flow form can lift upwards from 10 pounds with only 2 Bft winds, or 7 mph. Since parafoil and flow form kites are soft kites, they can be easily rolled into very small bags which allows for easy transportation. They may also be deployed in seconds due to their lack of required assembly. The use of parafoil and flow form kites is hindered due to their low flying angle. This means that these kites cannot be flown in congested areas. Additionally, since these kites can be unstable at times, many people attach a tail to the kite, preferably a “fuzzy” tail which can limit the capabilities of the kite (Le Riche, 2008; Leffler, n.d.).

The rokkaku kite is a framed kite type and is a very stable kite platform (Le Riche, 2007; Hunt, 2006). Framed kites have a rigid structure which is created by numerous spars that cross the kite. The rokkaku is known for being a stable lifting kite which makes it an ideal candidate for Kite Aerial Photography. The extra advantage that gives the rokkaku its stability is its bowed shape. The cross-spars are bowed in such a way that the lower spreader bar is bowed slightly more than the upper. However, the central spar must remain rigid to extend the kites area. The larger sail area along with its rigid shape gives the rokkaku not only stability but moderate lifting power. This type of kite can operate in 1 – 3 Bft or 3-12 mph winds and also boasts an adjustable flying angle. With an adjustable flying angle the rokkaku can be flown in both vast and tight air spaces as well as be adjusted to carry heavier loads. All of these attributes, especially its stability, make the rokkaku a mainstream kite aerial photography kite design. However, with all of these advantages come a few practical challenges. Firstly, any unevenness in bowing of the spreader bars may cause the kite to fly at unusual angles. Secondly, the assembly of a rokkaku on site requires some brute force when it comes to bowing the spars as well as when fitting the central spar. While this creates the tension in the kite that will keep it rigid, it is an obstacle to overcome. Transportation is not an issue, since the kite can be rolled up, and the spars collected.

Figure 5. A rokkaku style kite being flown.
Source: (Hurbain, P. Retrieved 2010, March 29 from http://www.philohome.com/kitephoto/rokkaku.jpg)

The delta kite and its variant, the delta conyne, are two other types of framed kites. Delta kites are easy to use in that they only require a cross-spar to be assembled on site(Le Riche 2007; Hunt, 2006). The other spars are already built into the frame, making its storage very easy. The

Figure 6. A delta style kite at a high altitude.
Source: (Hunt, D. Retrieved 2010, March 29 from http://www.kaper.us/basics/delta_R.html)

keel in the kite helps the kite maintain stability; however, if the cross-spar is too tight then the rigid bowing will cause the kite to become unstable, unlike the rokkaku. A very important aspect of the delta is that it can fly at very high angles as to utilize more of its pulling force in an upwards direction, providing more lift to raise camera rigs. However, they usually are lacking when it comes to pulling power and tend to be more suited for creating trains. A train of kites is a configuration where multiple kites may be attached together on one main line, and are spread apart such that they do not collide in the air. This is a very effective method to boost a kite's lifting capabilities; however, this does require multiple kites as well as tedious assembly. Delta kites are well suited for training, giving the option to carry heavier loads; however, due to their light wind capabilities, their usefulness in hindered. They are easy to construct and can be trained together to achieve the desired lift so they are still a widely used kite design in kite aerial photography.

The delta conyne is a marriage of the delta kite and the conyne kite (Hunt, 2006). The delta conyne takes the shape of the delta so the only assembly required is still the cross-spar. This design is more stable than the delta because of its dihedral sail panes at the tip of the kite. However, most of them do require some sort of tail so that they do not overfly. A key advantage is the open pane in the center of the kite, allowing for a line to be passed through the kite, making the delta conyne perfect for trains. Like the delta, the smaller variations of the delta conyne cannot lift most camera rigs, but larger

Figure 7. A delta conyne style kite showing its signature open pane.
Source: (Hunt, D. Retrieved 2010, March 29 from http://www.kaper.us/basics/dc

versions of the delta conyne kites are able to lift some weight on their own. The delta conyne is limited to a very small range of 2 – 3 Bft or 4-12mph for the smaller models, while larger models can fly in the same 1 – 3 Bft, or 3-16mph, as the delta. Similar to the rokkaku, the delta conyne also has an adjustable flying angle.

Sled kites are the most basic of kite designs (McCasland, personal communication, April 14, 2010). There are two built in spars that keep the vertical shape of the kite and two lines that meet up which hold the kite to the line. These kites are generally used for teaching younger people how to create their own kites as well as basic flying techniques. Once they are assembled once they are complete and only need to be rolled up when not in use. These kites are very useful in trains but cannot lift anything on their own. The sled kite is a simple and cheap design, but very lacking in lifting capabilities. It is a good candidate for teaching students about kites, but not for conducting kite aerial photography research.

Figure 8. A picture of a basic sled kite.

Source: (Columbus Municipal Airport. Retrieved 2010, April 18 from http://www.bakalar.org/FirstFlights/ff_sledkites.htm)

Depending on the quality of pictures that are desired, cameras can be the most expensive portion of Kite Aerial Photography. Cameras have evolved over the years to be more compact and lighter, which is perfect for Kite Aerial Photography. However, these digital cameras have certain drawbacks that may be malignant to the KAP process. According to Benton (2003), digital cameras at heights of about 200-300 feet do not often produce accurate results. Their shutter speeds are slower, and thus more light is allowed to enter the lens, causing problems with the exposure and clarity of the pictures. There have, however, been recent articles ("Objects of desire", 2008) which suggest that digital cameras will be able to record the quality images at such altitudes.

The device that holds the camera to the kite is also important and can be rather complex. There are numerous designs that are used by Kite Aerial Photographers, but the one that appears to be most popular is the Picavet suspension design, which was used by the Parramatta High School in their experiments and is the most common, according to Benton (2004). However, this is a fairly recent development considering that a pendulum type suspension was preferred through much of the past century. In 1988 Michel Dusariez wrote an article, published by the Kite Aerial Photographers Worldwide Association that revitalized interest in the Picavet design (Benton, 1999). The Picavet design is popular because of its tendency to keep the camera horizontal regardless of the kite's movements as well as nullify any jerky motions that might be felt by the kite. Other devices, such as servos, attached to the camera could be used to pan the camera or control when pictures are taken. These devices could be automated to take many pictures over time at different angles or actuated by a remote control.

Figure 9. A camera rig hung from a picavet suspension.
Source: (Haefner, S. Retrieved 2010, October 3 from http://scotthaefner.com/kap/equipment/picavet/

A widely used, although somewhat expensive, option is to have the camera and camera rig remotely controlled or automated. This is a much more involved device but it has many advantages. By doing so, one eliminates the need to constantly take down and deploy the kite repetitively in order to change the direction of the camera (Bults, 1997). There are systems that are automated to take photos every few seconds after the camera pans to readjust for the next shot (Leffler, n.d.). On the other hand, with a radio control system the photographer has more precise control over what images are being taken. Older remote control sets can work perfectly fine with Kite Aerial Photography and are recommended because they can be purchased at much cheaper prices than newer sets (Bults). Typically, a 4-channel remote is ideal since it leaves you with options such as controlling the tilt of the camera, the pan of the camera as well as control over when a picture is taken. However, it may be cheaper to purchase a 2-channel remote and simply bring the kite down if the tilt needs to be adjusted (McCasland, personal communication, April 14, 2010). The remote is powered by batteries, but picking the right ones is important when it comes to price and battery life. The most commonly used battery type is the nickel cadmium since it is rechargeable, has decent battery life and the costs involved are minimal when compared to other non-rechargeable batteries such as alkaline or lithium batteries (Hunt, 2006; Bults).

These components must be able to work in unison in order for the Kite Aerial Photography system to perform at its best. The kite or kites need to be able to function properly in the wind conditions at the photography site as well as be able to lift the camera and the camera rig. The camera must be able to take clear photos from the height it is at and be tuned correctly for the time of day. The camera rig should be keeping the camera level the entire time and if required be able to adjust the camera's angle as well as take pictures, either automatically or manually.

Balloon Aerial Photography

Balloon aerial photography consists of three main components: the balloon, the gas source and the camera with its rig. Among the types of balloons that are available to the public for balloon aerial photography are normal weather balloons, party balloons, and trash bags.

Figure 10. A picture of a helium balloon.

Source: (SkyDoc Systems, LLC. Retrieved 2010, September 6 from http://www.skydocballoon.com/

Among these types of balloons, weather balloons provide the simplest requirements in order to achieve balloon aerial photography. Varying sizes of weather balloons may be purchased online with ease. Most weather balloons come in 3, 8 and 12 foot diameters. In order to launch a weather balloon for aerial photography, one would simply fill the balloon with the desired gas, launch the balloon, and affix the camera on the tether at the desired height.

A variant of the weather balloon is the SkyDoc-style of weather balloon. The difference between a standard weather balloon and this style of kite is the hood that is affixed on the back of the balloon. This allows the balloon to capture any win, tilting the balloon, and giving it behaviors similar to those of a blimp. This allows the balloon to travel through the wind, reducing the amount that the balloon is affected by the elements.

After weather balloons, simple party balloons are the simplest balloon with which to achieve aerial photography. There are two different types of party balloon that can be used, latex balloons, which are commonly 9" in diameter, or mylar (Biaxially-oriented polyethylene terephthalate) balloons. While they provide more lift and are more resistant to popping, mylar balloons are not biodegradable, and therefore have attracted some controversy in the use of balloon aerial photography. In order to fly either of the two types of party balloons, each balloon must be inflated, and grouped with enough other balloons to provide adequate lift to raise the camera and camera rig to the desired level.

Figure 11. A picture of common mylar balloons.

Source: (AAA Balloons. Retrieved 2010, September 15 from http://www.aaaballoons.com/

Garbage bag balloons are the most difficult balloons to use for balloon aerial photography, solely due to their construction. A garbage bag balloon is, in actuality, a form of a hot air balloon, formed by patching together multiple garbage bags. Rather than a mounted torch, this type of balloon is heated just by the sun's heat, thus their name, Solar Balloons. The black surface of the garbage bags are conducive to collecting heat from the sun, and therefore provide some of the best material with which to construct the balloons. This is one of the main advantages of the solar balloon. As long as the sun is out, the balloon can fly all day, without and refilling or reheating, allowing for easy flights.

Most commonly, helium, hydrogen and methane are used as the gases to fill the balloons in BAP. However, each of these gases has its own drawbacks. Hydrogen has seen only limited uses in balloons since the Hindenburg disaster. Although it provides a significant amount of lift, its flammability is a major concern. Methane is a very inexpensive gas, however, it provides significantly less lift than hydrogen. Helium is the most stable of the three gases, and provides the most lift. While being a more expensive option than the previous two gases, helium is used in all airships today, and most balloons as well.

Figure 12. A picture of Long Island taken from 17.5 miles.

Source: (1337arts. Retrieved 2010, September 15 from http://space.1337arts.com/

A major difference between kite aerial photography and balloon aerial photography is the necessity of a tether. Whereas in kite aerial photography, the kite must always be tethered to the ground in some way, balloons do not always require a tether. When tethered, both kites and balloons are not allowed to exceed a 500 foot altitude, as regulated by the Federal Aviation Administration (FAA). However, when untethered, balloons may fly as high as desired, or until the balloon pops due to the decreased pressure and temperature in the upper atmosphere, so long as the balloons payload remains under four pounds (http://www.faa.gov/regulations_policies/). This unrestricted flight allows for much higher photographs to be taken. In 2009, MIT student Oliver Yeh used a standard weather balloon, equipped with digital camera and hand warmers (to counteract the temperature change in the upper atmosphere) to take photos from approximately 93,000 feet.

The camera rigs used with the kites are also applied in the balloon aerial photography, so the resulting images should provide the same level of resolution, viewable angles, shutter controls, etc.

Chapter 3: Methodology

This project aimed to set up a system by which the long term health of vegetation in the Boston area could be tracked through the use of aerial photography systems. The goal for this project was to develop a curriculum for students between the 5th and 9th grades, which could be implemented in the greater Boston area, allowing the students to remain involved with their usual curriculum as well as track environmental health. In order to achieve this goal, we executed three main objectives:

1. We analyzed the current equipment and programs used by the Blue Hill Observatory.
2. We determined the optimal design of the kits that can be provided to schools.
3. We designed and tested the desired curriculum.

Objective 1: Analyzing Current Procedures

The objective of our analysis of current kit designs was to create a kit for students that was both cost effective to purchase or could be rented to interested parties. Each portion of the kit was analyzed separately. First, we analyzed the different types of kites and balloons on the market that are available for aerial photography. Currently, for their own use, the Blue Hill Observatory uses rokkaku and parafoil style kites, and for the student's use, the observatory uses easily constructed Sled kites, which have been affectionately named "Frustrationless Flyers" due to their ease of use and construction. The qualities of each kite that vary are the size, varying from 4 to 10 feet across, and the style of kite. We tested four main styles of kites, the rokkaku, the delta, the parafoil, and the sled. In addition to these, we tested two styles of balloons. The first of these was the standard helium weather balloon, and the other was a variation of this balloon, in which an additional hood allows the balloon to behave like a blimp. In order to determine which vehicle best fit the needs of the Blue Hill Observatory, we flew the different styles of kites, each of varying size, as well as the balloons. While doing so, we affixed different camera rigs, both the normal Brooxes rig, and our homemade rig[5] to the lines, in order to determine the maximum lifting capacity of each. This allowed us to judge whether the each kite and balloon would be appropriate to be used for aerial photography. The lightest camera rig that was attached to the line was the homemade rig, which, due to the rig being cardboard, was barely heavier than the camera. The heaviest rig was the picavet suspension Brooxes rig. Each kite or balloon was flown to between 100-200 feet, the altitude at which they will most likely operate while being used by the students. If a kite or balloon had any trouble lifting the rig in unstable, light, or turbulent wind conditions, the vehicle was ruled out of contention. Once we had completed this, we formulated a matrix containing the results of our testing, displaying vehicle size versus maximum lifting capacity. We then created matrices displaying size of the kites and balloons compared to the cost of that size and style of kite. We used the principles of Cost Benefit Analysis[6] to analyze this data. In order to do so, we developed a cost itemization of everything required to create the kits. After coming up with a total cost for all of the items, we compared this to the time required for a Blue Hill Observatory representative, assuming a standard fee for services, a rate of $120 for the first two hours of any visit, and $45 for each additional hour.

An additional strategy that we examined was to have the students build the kites themselves. In order to do this, students are supplied with a 51"x51" piece of nylon[7], an ample supply of ¼" dowels, a roll of duct tape, and approximately five hundred feet of 80 pound test line. After each student is supplied with their materials, our team teaches the students about each

[5] Our homemade rig was constructed from a used orange juice carton, as seen in Appendix G
[6] See Appendix D
[7] The size of the sheet was determined by the size in which they are available.

of the types of kites that are viable with a sheet of this size, which in this case, are rokkaku, diamond, and delta kites. In order to test whether this was a viable option, the team built each kite from the given materials. If the kite building exercise took longer than 90 minutes, the activity would not likely be viable in the classroom. In order to build the kite, the nylon is cut into the desired size and shape and then the dowels are used as the spreader bars. The next step was to affix a bridle to the kite. This is done by opening a hole in the sail material, and affixing the line to the dowels. When the homemade kites were built, they were then tested in the same fashion as the kites that are commercially available. However, in testing these, it was understood that the size and quality of the kites would not support a heavy camera rig, and thus only tested with the lighter, homemade rig.

The next piece of equipment that we investigated was the camera that was to be used for the aerial photography. Currently, the Blue Hill Observatory has used a Canon A560 in order to take its pictures. We conducted research in order to find out which camera would best fit the Blue Hill Observatories needs. We compared the advantages of analog and digital cameras. The features of the cameras that we were most interested in are the cost, weight, shutter speed and the ability to program the camera. We used websites and search engines such as Craigslist, Google and eBay, to locate desirable cameras at lower than market price. Before each camera could be tested, we had to first verify that they could be lifted by the kites that Blue Hill Observatory currently uses. We used consumer reviews as an important factor in deciding which camera would best fit the needs of the observatory, since it would be counterintuitive to purchase the camera for the use of testing. We found sample photos taken by each camera, compared the images, and used a basis of clarity and resolution width to try to determine which camera was able to take the best photos. We compared key traits of each camera, such as its megapixels, optical zoom and available camera modes to the cameras price, as was done with the kites and balloons.

Next, we analyzed the rigs to which the camera will be fixed. The options that we explored were the picavet suspension that Blue Hill Observatory already uses, a 2-channel variant of the picavet suspension that pans and tilts, but does not have a shutter release, and a pendulum based rig that is not activated by a remote control. The first option utilizes a 3-channel remote control (RC) unit, which controls the shutter, pan and tilt of the camera. The second option utilizes a 2-channel RC unit, controlling only the shutter and pan of the camera. The advantage of this rig is that it can function off of a 2-channel controller, whereas a 3-channel rig would need to use a 4-channel RC, as 3-channel remotes don't exist. The disadvantage of the 2-channel rig is that the kite camera must be reprogrammed to take pictures at a set time interval, usually six seconds. The reason that this was unfavorable was because the SD card within the camera must be large enough to contain the quantity of photos that will be taken, thus shortening the flight time. The final option, which requires no remote control, controls neither the pan, tilt, nor shutter; however, it keeps itself stabilized using an aluminum pendulum system. The main concern in choosing the rig was the cost. The 4-channel RC unit is the most expensive, usually costing between $300-400. The 2-channel unit is considerably less expensive, at approximately $80-100. The pendulum system is easily the least expensive, with most of the rig being easily constructed out of scrap aluminum. The quality of the pictures was heavily considered, as the stability of the rig directly influences the clarity of the pictures. We also considered the difference in difficulty to control each rig.

Another aspect of the kit design that evaluated is the ease with which the kits can be constructed. The team completed this task using a simple methodology. We had each member construct the kit individually. This was timed, so that we could compare the times required for each kit. Each group member performed the process 3 times. By doing so, averages could be calculated, and the results could be visualized. This process was only repeated once for the homemade kites, as the process is far more time consuming, and students will only have the materials to attempt the design once.

The final item that we analyzed was the Measuring Vegetation Health programs that are available on the MVHimage/Digital Earth Watch website[8]. The MVH website has multiple software programs available, each with different methods to monitor vegetative health. The programs that are available from the site are Color Basics, Digital Image Basics, Analyzing Digital Images, Forest Analysis, and Vegetation Analysis. Since these programs are some of the only programs that are used for this type of analysis, we solely tried to determine which of the software would be best to use in the classroom. In order to do this, each program was downloaded, and then the same picture was uploaded into each program. The programs were compared against each other based on the grounds of how easily we could manipulate images.

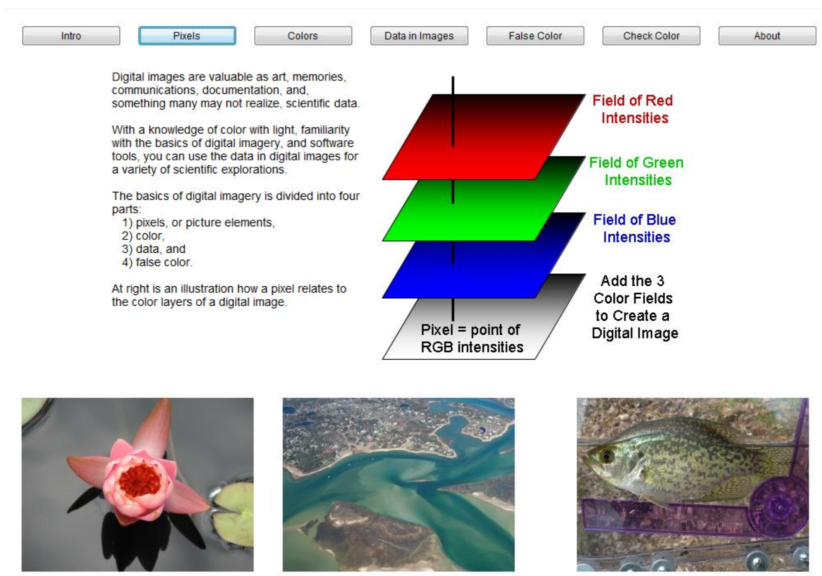


Figure 13. The main interface of MVH/DEW DigitalImage Basics program.

Source: (http://mvh.sr.unh.edu. Retrieved 2010, October 3 from http://mvh.sr.unh.edu/

[8] Programs are available at http://mvh.sr.unh.edu/index.htm

In order to assist us in our picture analysis through these programs, we created a database for our pictures via Facebook[9]. By creating a Facebook page for the WPI-Blue Hill Observatory Kite Aerial Photography, we created a common area from which we, as well as teachers and other enthusiasts, may access our pictures from various locations and dates; this allows for teachers, students and hobbyists to both learn about kite aerial photography and use our photos in the MVH programs to track vegetative health.

Objective 2: Kite Kit Design

Using the data that were generated in the first phase of the project[10], we were able to determine which kite/balloon/camera/rig combination is the best combination for the needs of the Blue Hill Observatory. We compared all of the data we collected, compiled the maximum lifting capacity vs. cost, kite/balloon size vs. cost, and our cost analysis of the cameras and camera rigs. While considering each combination of kites, cameras and camera rigs, we considered that some of the smaller kites will have a lifting capacity less than the weight of some of the rigs and cameras that were tested.

In analyzing the data that were collected over the experimentation, the team determined that it will be considerably more beneficial to the Blue Hill Observatory, and the local schools, to create two separate kits. Taking into consideration the various needs of the schools, and the wide spread of demographics across the state of Massachusetts, it was best if the two kits would be able to support both ends of the financial spectrum. The first kit was comprised of a commercial kite and the RC Brooxes rig, which would be available to rent through the Blue Hill Observatory. The second kit was comprised of the material required to make a homemade kite and a

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[9] The site can be found at http://www.facebook.com/#!/pages/WPI-Blue-Hills-Observatory-Kite-Aerial-Photography/147989138566681?ref=ts

[10] See Objective 1: Analyzing current procedures

homemade rig, which schools could either buy from the Blue Hill Observatory or from a local hardware store.

We then attempted to maximize the ease of use of each kit. Among the ways in which we attempted to do this are to analyze the number of steps required from the building of the kit, to the effort required to take pictures while flying the kite. We aimed to have the fewest number of steps as possible, as to make the kite kits accessible to student from grades 5-9.

Objective 3: Curriculum Design

While constructing the each of the kite kits, we had to determine how to teach the students about mathematics and science. Since the homemade kites required more precision, measurement, and assembly, it was determined that its use would accompany the mathematics curriculum.

In accordance with the Massachusetts Curriculum Frameworks seen in appendix C we developed a curriculum for students between grades 5-9. The mathematics curriculum was designed reinforce the use of ratios and proportions, the use of fractions in estimating and computing problems, sum of interior angles of polygons, and other algebraic and geometric properties. Students were taught about ratios, proportions, and fractions through the installation of the spreader bars on the different types of kites. For example, the spars on the rokkaku are placed further up on the body of the kite than on a delta. Sums of interior angles are covered through the cutting and construction of the sail of the kite. By returning to basic geometry and reviewing differences between a four sided polygon and a six sided polygon, we were able to apply the notions of degrees and angles to concepts that the students have already firmly grasped. For example, a rokkaku kite is hexagonal, whereas a delta kite is a triangle. The sums of the interior angles of these two shapes are 720° and 180°, respectively. This lesson can be taken further, by using the triangular shape of the delta kite to derive the formula for interior angles, $sum\ of\ interior\ angles = (n-2) * 180$.

After the construction of the kites, students bring their work outdoors and fly their kites. Since there will be more students than kites, the students who are not actively flying kites would be taking notes on the flight of both their own kite and the kites around them. This will culminate into a discussion in the classroom in which the students use critical thinking to determine why one kite may have flown better than others. Reasoning for this that is covered in the curriculum are the style of kite, the curvature of the spreader bars, and the surface area of the kite sails.

Our pre-constructed commercial kite kit was determined to be more beneficial to the science portion of our curriculum. Since the kit requires less construction, students are able to get the kite into the air much quicker, and are able to lift the RC unit and camera with ease. This allows the students to retrieve the photographs that are desired, such that the pictures could be applied to the MVHimage software.

Within the sciences, the aerial photography reinforced the principles of earth science and life science. According to the Massachusetts Curriculum Frameworks (2000), students in grades 6-8 "gain sophistication and experience in using models, satellite images, and maps to represent and interpret processes and features" (p. 23). In order to reinforce these principles, we developed a way in which the images that the students take with the KAP can be used in the classroom. The photos that are taken by

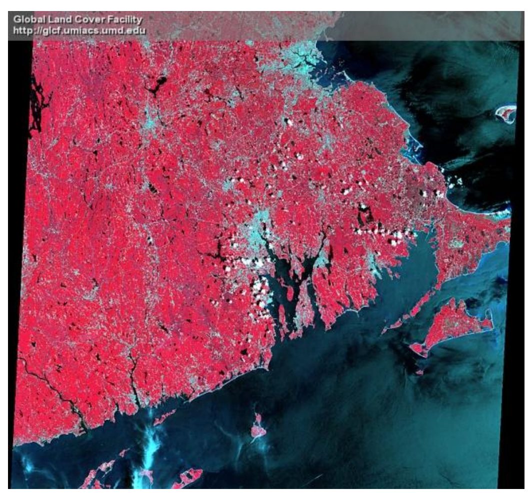


Figure 14. A picture of eastern Massachusetts put through a LANDSAT light filter.

Source: (http://mvh.sr.unh.edu. Retrieved 2010, September 28 from http://mvh.sr.unh.edu/

the students will be the focus of questions that further students understanding of reading satellite images and maps. To do this, we worked with the teachers to determine how the pictures may relate to the covered material. An example of how this is done is through existing satellite images of the vegetation. When a satellite image of an area is taken, each pixel of the image represents a 30'x30' area. Therefore, the students aimed to take photos of specific 30'x30' areas, and matched them up with existing satellite images. This reinforced the students' ability to read the satellite images, and learn how to understand the scaling of a map, all while providing practice in aiming and coordinating the camera. Additionally, the MVHimage software allows the students to analyze the health of the vegetation around their school.

Once again, the use of this kit will culminate in a classroom discussion. However, this discussion is focused on the health of the ecosystem near their school. We will ask them thought provoking questions, which will require critical thinking and observation skills in order to figure out. For example, one question we could ask would be "why was the one end of the pond near the athletic fields covered in algae, while the rest was clear?", as was the case at Braintree High School. The answer to this, of course, was that runoff of the fertilizer allowed extra nutrients to enter the pond at that point, inducing growth of outside species.

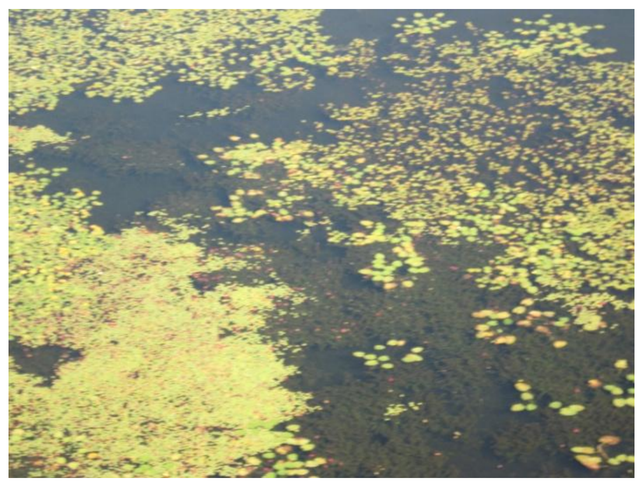


Figure 15. Algae on Sunset Lake near Braintree High School.

Source: Taken by Blue Hill Observatory/WPI team. 14 September 2010

In some situations, the teachers at the schools we were involved with found it more appropriate that they carry out the lesson, rather than our team. For such cases, we developed a tutorial and lesson plan[11] aimed towards informing the teacher on how to properly operate the equipment. We demonstrated for the teacher how to construct, and then deconstruct, the entire kit, from arranging the kite, attaching the picavet rig, and how to appropriately fly the kite. From there, we taught them how to use the remote control to take pictures. Immediately following our demonstration, we had each teacher twice perform the construction and deconstruction of the kit on his/her own, which ensured to us that the teacher will properly demonstrate and instruct the students how to construct and operate the equipment, so as to prevent damage to the Blue Hill Observatory's equipment.

After carrying out the lesson plans, students are provided with a data collection matrix[12], with the goal of gauging the effectiveness of our program. Students are asked about the impact of each portion of the lesson plan. At the end of each program the matrices are collected from the students, and their data is compiled. From there we used the data that the students provided us to improve our curriculum in the areas they deemed weakest.

[11] An example of a sample lesson plan is seen in Appendix H
[12] As seen in Appendix K

Chapter 4: Results

Curriculum Development

Our analysis of the kite aerial photography equipment and the MVHimage programs that would be used alongside the equipment revealed that it would be most beneficial to develop two different curricula which could be alternated within schools to accommodate their wants and needs. The first of the two curricula is the Mathematics and Engineering Curriculum. This curriculum has students designing their own kites, from the materials that the Blue Hill Observatory supplies to schools. Each kit is comprised of a 48” by 48” sheet of ripstop nylon fabric, three 5/16 inch diameter wooden dowels, a pair of scissors, a roll of duct tape, and approximately 200 feet of 150 pound flying line.

Table 1.Associated costs of the Mathematic and Engineering Kite Kit

Item	**Cost per unit (USD)**	**Total Cost**
48”x 48” sheet of ripstop nylon fabric	$11.50 per yard	$15.00
5/16” wooden dowels	$0.78 per dowel	$2.24
Flying line	$2.00 per handle	$2.00
Duct Tape	$1.50 per roll	$0.15
Total Cost of Kit	--------------------------	**$19.39**

As can be seen in the above chart, the costs for the Blue Hill Observatory kite kit amount to slightly less than twenty dollars per student, before considering personnel fees. Certain materials, such as the scissors and duct tape, may already be provided by the school, so they were discounted. It should be noted that if purchased individually the kit may cost up to thirty dollars, as the flying line is more expensive when it’s not bought in bulk; however, the Blue Hill

Observatory offfers a discount on the entire kit. Another option that is viable for the Math and Engineering Curriculum is to use the Frustrationless Flyer kits. These kits are much less expensive, selling for approximately five dollars per setup. However, the use of this kite reduces the relevancy and effectiveness of the curriculum.

The other kit that is available to schools is the Science and Technology Kit. This kit uses the kites that Blue Hill Observatory already owns in order to teach the students about principles in the Life and Earth Sciences. Schools will be able to rent or buy their own kites, as well as the camera rig and the camera, from the observatory. While the purchase of the aerial photography equipment will be more expensive than its rental, it will allow the school to repeat the program for multiple years.

Through our research, we determined that the use of digital cameras would benefit our sponsor better than an analog camera. This was due to the lower cost, weight, and size of the digital cameras, accompanied by the fact that the cameras could be hacked to take pictures at set intervals. A common trait across most Canon digital cameras, including Powershot models and the A560 that the Observatory already used, was its ability to be hacked. By importing a script onto the SD Memory card, the camera can be programmed to take pictures at variable intervals.

Table 2. Associated costs of the Science and Technology Program

Kite/Camera/Camera Rig	Cost to Purchase	Approximate Cost to Rent
7' Delta Conyne Kite	$49.00	$10.00
11' Delta Kite	$169.99	$35.00
30' sq. Flow Form Kite	$119.99	$25.00
Canon A560 Camera	$299.95	$20.00
Homemade Camera Rig	Free	Free
Brooxes Deluxe Rig w/ Remote	$153.00	$40.00

As can be seen above, the itemization of the necessary equipment shows that this kit is more expensive than the Kite Building kit; however, there is a much larger range of versatility with this kit. Firstly, not all of the kites are necessary. They vary by the wind conditions, and will therefore change based on the day in which the program is carried out. Secondly, schools that already own their own cameras can exclude the associated cost from the rental. Thirdly, schools can reduce the cost of our kit significantly by using the homemade rig[13]; however, there is a significant tradeoff, as the Brooxes rig is an excellent medium to teach students about radio signals, servos, and gear systems. A final option to reduce the cost of the kit is to substitute the kites with weather balloons. This is beneficial for schools if they would like to include mathematics into this curriculum, as it does an excellent job teaching students about volume and rate of change algebra.

[13] Seen in Appendix G

School Programs

Our first school visit was to Braintree High School on September 14, 2010. Our program took place after school, where we met only with Environmental Studies teacher, Matt Riordan. Mr. Riordan invited us to the school in order to take pictures that he could then use in his Environmental Studies class, incorporating the pictures in his curriculum plan of using Google Earth and ARCview for mapping exercises. While the team captured pictures that would be beneficial to measuring vegetation health, such as the small riverbed leading into the pond, we were unable to receive any results regarding our in-class program. This was due to the fact that we did not have any contacts with the students, as our photography took place after school hours.

Figure 16. Sunset Lake near Braintree High School. Algae can be seen in the lower portion of the picture.

Source: Taken by Blue Hill Observatory/WPI team. 14

In a follow up with Matt Riordan, our team was able to gather information on how the pictures were to be used within his classes. The first way that Mr. Riordan planned on using our pictures was to have students learn about the aquatic life that was growing in and around Sunset Lake, located across the street from Braintree High School. Of the pictures, Mr. Riordan said:

I would like to use them to have the students make comparisons that they would not otherwise get to see, such as the increased algae and aquatic plants that are along the shoreline and not in the middle of the lake. We would use their presence or absence to talk about limiting nutrients, range of tolerance, fertilizer use and fertilizer runoff. (Riordan, Personal Communication)

In conjunction to teaching students about the aquatic life near the school, Mr. Riordan planned on integrating our pictures into his work with Google Earth and GPS units. Mr. Riordan had students use the images taken near the school to find landmarks, determine an associated latitude and longitude, and then overlay these images into Google Earth. The goal would be to "create a presentation using Google Earth that shows changes in aquatic biodiversity."

Figure 17.Satellite Image of Braintree High School and Sunset Lake.

Source: (http://www.maps.google.com) Retrieved 1 October 2010

As a final note, Mr. Riordan suggested to us that we make more use of balloon aerial photography. He noted that while it would be more expensive, it has the potential to be more accurate, being capable of locating exact positions.

The next visit that our team made to a school was on September 29, 2010, at Math and Science Academy in Greenfield, Massachusetts. We carried out the entire kite building activity, and its corresponding curriculum[14]. Due to time constraints, we were not able to analyze our

[14] The activity and the corresponding curricula can be found in Appendices G and I

pictures with the students; however, we were able to cover our entire mathematics curriculum. At the end of our program, we asked the students and teachers what they thought would improve our program. Some of the responses we received from the students were to spend less time on covering interior angles, and the actual kite building activity, and to devote more time to the kite flying. Another suggestion that we received from the students was to track the weather before our program, so we can come on a day where the weather conditions were favorable for flying.

One portion of our program that is crucial to its success is whether the students have the opportunity to fly the kites. This is the portion of the curriculum that the students looked forward to the most, and it helps us better understand how many students were able to retain the information that we provided during the kite-building activity. Hypothetically, we can assume that each of the students who had successful flights understood the different aspects of engineering needed to construct the kites. We were able to define a "successful" flight as any kite that gains and maintains a steady altitude after launching the kite, or while the student is still running. A "sub-par" flight can be defined as a kite that gained altitude during launch, but was not able to maintain its altitude. A "failed" flight is classified by a kite that is not able to attain any form of flight, due to the bowing of the spreader bar, symmetry of the kite, or the aspect ratio. Through these classifications, we were able to characterize the results of the fifteen students at the Greenfield Math and Science Academy:

Table 3. Flight data from Greenfield Math and Science Academy

Classification	Number of Students
Successful	11
Sub-par	2
Failed	2

Of the fifteen students at the school, eleven of them, or 73.33 percent, had successful flights, while the final 26.67 percent is split evenly between "sub-par" and "failed" flights. Through our analysis, we determined the flights within the "sub-par" category are inconclusive, and should be excluded from our study. This was chosen because it cannot be determined whether their limited success was due to a combination of good understanding of the material and bad luck and conditions, or poor understanding and substantial luck. The "luck" and "conditions" that are referred to are wind strength, wind turbulence at their position, and potentially damaged materials. Therefore, we can estimate the success rate of the program to be somewhere between 11 out of 15 (73.33 percent) students and 13 out of 15 (86.67 percent) students.

The students from the Greenfield Math and Science Academy were provided with a quiz[15], as well as the previously mentioned Data Collection Matrix, about our material one week after the program, in order to determine how much information was learned and retained. The results, seen below, were particularly underwhelming, with average test scores below ten percent.

[15] See appendix L

Table 4. Quiz data from Greenfield Math and Science Academy

Question	**Topic Covered**	**Number of Correct Answers**	**Percentage of Correct Answers**
1	Interior Angles	0	0%
2	Interior Angles	0	0%
3	Algebra	3	20%
4	Area and Ratios	0	0%
5	Pythagorean Theorum	0	0%
6	Kite Flying	3	20%
7	Technology	1	6%
8	Science	1	6%
9	Kite Aerial Photography	3	20%

There were fifteen students in the class, and out of the collective student body there were eleven total correct answers. Therefore, of the 135 questions that were distributed to students, only eight percent of answers were correct. From this we can tell that the retention rate of our original program was extremely low. Additionally, we can infer that the students did not learn much, if any, of the material that we attempted to teach.

The data collections matrix yielded significant insight on the direction of our program[16]. We found out that among the topics that we discussed, Engineering attracted the most interest by a wide margin. Through future analysis of these results, it would be determined how to adjust the program accordingly.

The teachers from the Math and Science Academy, Heather Evans and Darcy Albanese, suggested to us that we bring worksheets for the students to work alongside us while showing the

[16] See appendix M for compiled matrix data.

students examples on the board. The intention in this is that worksheets will allow the students to grasp the concepts in the short run, as well as retain them for a future learning. Additionally, the teachers agreed that showing students alternate solutions to problems was beneficial to their learning, as the students could see and relate separate solutions to the same problem. For example, our team taught the students how to calculate sums of interior angles in a different fashion than they had been taught in previous years.

In order to improve the future effectiveness of this program, our team began to develop modules for our curriculum. Each individual module lays out a short lesson plan, with each lesson plan ideally taking less than an hour. By breaking the program down into modules, the program will be more manageable for teachers in the future. The modules that our team developed are Kite Design and Associated Mathematics, Kite Building, Kite Flying, Technology, and Measuring Vegetation Health.[17]

Programs and databases

Through the Measuring Vegetation Health website, we had access to five programs that have been used to track vegetation; these being Color Basics, Digital Image Basics, Analyzing Digital Images, Forest Analysis, and Vegetation Analysis. We downloaded each of these programs and used images collected from Whitcomb Summit and Braintree High School in order to analyze which software did the best job of measuring vegetation health. Unfortunately, the link to the Analyzing Digital Images was corrupt, and we therefore could not use this program. Of the remaining four programs, the Color Basics and Forest Analysis were next to be ruled out. Color Basics does not allow images to be uploaded into the program, and only allows the user to

[17] Modules can be seen in Appendix N

mix colors. The Forest Analysis program only shows existing maps of the forests in the United States. Once again, users cannot upload or interact with images. Vegetation Analysis also had to be eliminated. The program looked promising at first, allowing for the user to upload up to three images. However, a flaw in the program seems to exist, as upon uploading the images, the program asks for a timetable as to when the images were taken. This is a problem as the programmer never included a place to input this data, thus causing the program to set itself in an infinite loop. This left Digital Image Basics as the final program, which proved to be the perfect program for our needs. The program allows the user to upload an image, and then interact with the resolution and light filtering of the image. Below are two images of Chernobyl, Russian, one taken within a month of the Chernobyl nuclear power plant disaster, and the other taken six years later.

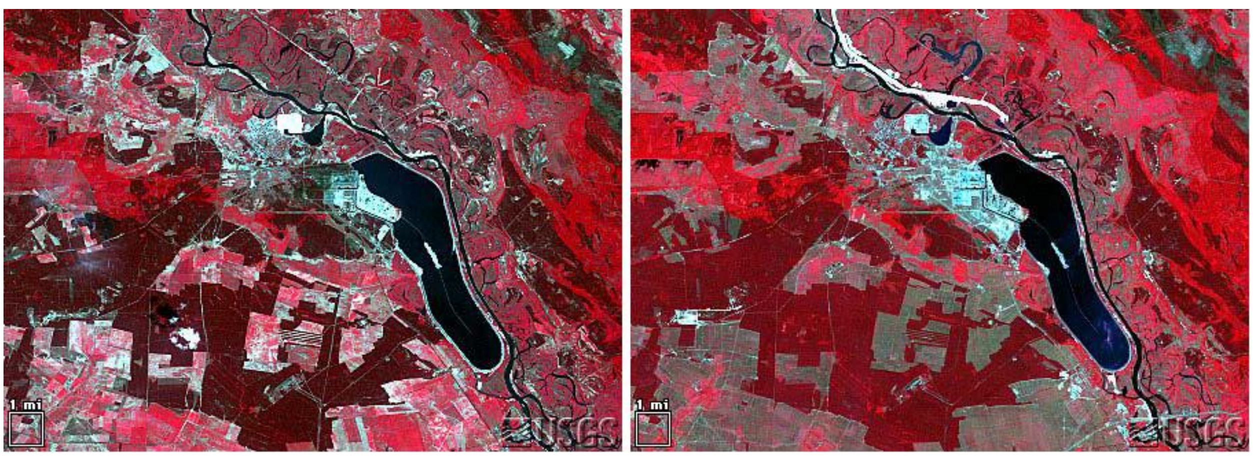


Figure 18. Left: Chernobyl, Russian, 1986. Right: Chernobyl, Russian, 1992

Source: < http://www.lawrencehallofscience.org/gss/dew/software/guides/IDI-sb.pdf>
Retreived 13 October 2010

Through the infrared light filter, healthy vegetation shows up as a red or pink color, indicating whether specific vegetation is undergoing photosynthesis. The deeper the red coloring on the picture, the healthier the plant life is. Unhealthy vegetation shows up as gray or blue, which indicates that the vegetation has either died, or is still too young to achieve full photosynthesis.

As can be seen in Figure 18, the vegetation around the power plant was still very healthy just a month after the explosion. However, in the image on the right, it can be seen that six years has reduced the health of all of the vegetation around the plant. This program is perfect for the curricula that are planned for the students, as it provides an easily explained and understood way to determine whether vegetation is healthy.

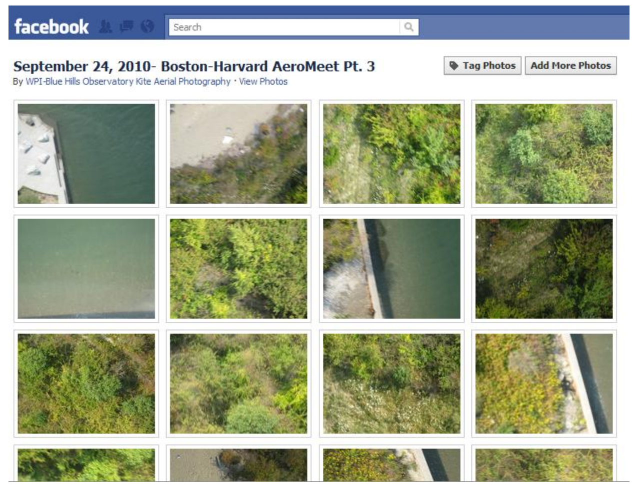


Figure 19. A sample of one of our albums, showing both blurry and non-blurry images.

Source: (http://www.facebook.com) Retrieved 3 October 2010 from http://www.facebook.com/pages/WPI-Blue-Hills-Observatory-Kite-Aerial-Photography

Over the course of our project, we received extensive feedback from fellow kite enthusiasts about our Facebook page. There was criticism from a few colleagues expressing concern over an excess of blurry pictures in the albums that our team had posted. This concern was well appreciated and this was adjusted by moving and blurry and out of focus pictures into their own album. However, we chose to leave the pictures on the website for two reasons. First, we must be able to show both the upsides and the downsides of kite aerial photography. Blurry photos that are caused from unsteady flight is on such problem. The second reason that we chose to leave the blurry and out of focus pictures on our webpage is that students are still able to use these pictures in the Digital Image Basics program. The Digital Image Basic program does not require pictures to have a high resolution in order to give an accurate infrared result.

Chapter 5: Recommendations

Test Reviews

In our experience, the evaluative test given at the end of the program was not an applicable measure of the effectiveness of our program. This was because we were unaware as to what the students already had learned. Therefore, we recommend the distribution of pre and posttests to students participating in the curriculum. By giving the tests before and after carrying out the program, a baseline of the students' knowledge can be produced, and their development can be more easily measured and analyzed. As a result of the tests, the two scores can be compared to show the effectiveness of the curriculum. This process could identify which topics were harder or easier for students to understand, which will allow future teams to determine the appropriate difficulty level of STEM material for each grade level.

When combined with the surveys, the results from these two tests could also provide other important findings, such as the interest of the topic as well as how organized the class activities were for the session. While the tests are very helpful to the Blue Hill Observatory, allowing for the adjustment of the program, these tests are also useful for the teachers. By making the test scores available to the teachers, they may be able to use them in future lessons, being able to later reinforce the points that stuck with the students, and to go over those that were confusing to the students. As more schools administer these tests, the analysis to gauge the effectiveness of our curriculum will become more conclusive.

Equipment Checklist

When starting an activity, it is important to have all the pieces necessary to complete the assigned tasks. A group that uses aerial photography might not always be able to complete a successful flight, due to missing, broken, or underperforming equipment. If the camera rig is not properly attached or the battery in the remote control is not properly charged, then it is very unlikely that all things would run smoothly. Therefore, we recommend that future teams working with the Blue Hill Observatory develop a checklist for the equipment used for aerial photography. A checklist of materials is important because you may only be able to fly in certain areas or time periods, and it is important to be able to prepare quickly when constrained by such parameters. The list or spreadsheet is also helpful because it keeps a record of all existing materials, and the conditions that they are in. Therefore, if a group wants to replace a part or buy an entirely new kit, then the costs for the desired materials could be easily calculated.

Plan the Program around the Weather

During our visit to the Math and Science Academy in Greenfield, a student had mentioned to our team that we should have come on a day when there was wind, so students could have a more enjoyable kite flying experience. Since the Blue Hill Observatory is the longest continually operating weather observatory in America, this is not outside the realm of possibility. Therefore, we recommend that future teams, in conjunction with the Blue Hill Observatory, use weather readings to determine the best day for a kite flying activity. Provided that the schools have open availability, an entire week may be set aside for the Blue Hill Observatory to determine which of those days would be optimal for kite flying.

Creating Visual Aids

Visual aids play a very significant role in attracting students to learning a subject or topic in school. Presentations should not contain titles and text only because the students would be less likely to pay attention or engage in the activities. Since visual learning is one of the three ways in which people learn, our curriculum has to include some type of graphics, such as posters, magnets, computer displays and more. We recommend that a system of visual aids be developed for use within the classroom, as to keep students interested and involved with in-class lessons.

If a poster were to be constructed for the program, they can display different variations of kites. This poster can contain Venn diagrams comparing the different kite types, teaching students why certain kites are more appropriate for different situations.

The advantage of using magnets as a visual is that they can be manipulated, on a white board or a chalk board to provide students with a spatial understanding of different shapes. These pieces can be arranged to show how some complex shapes are made up of the very basic shapes. For example, a diamond kite can be represented with multiple variations and configurations of triangles. Related to the concepts of magnets would be the use of tangrams. A tangram is a puzzle made of seven flat shapes, which can be rearranged to make a multitude of different shapes. By providing students with a set of tangrams, future teams can use the basic shapes to teach students about area, perimeter, and other related topics.

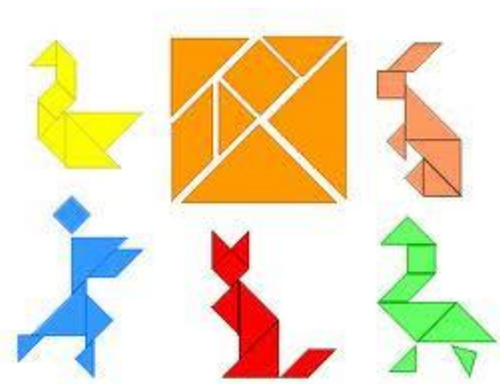


Figure 20. A tangram puzzle and a few shapes that can be constructed.

Source: (p6den.blogspot.com) Retrieved 10 October 2010

Computer displays can present the aerial photography pictures so that the students can see the type of pictures that they will be taking with their own cameras. They may use the Measuring Vegetation Health software on their own, and with their teachers, with the hope of influencing the students to come up with their own creative thoughts and ideas to explain what they find.

Creating Student Worksheets

Lectures have long been a traditional method of teaching, yet often deter students from learning. By adding worksheets to the curriculum, student interest in the program can be improved. By developing and incorporating this into the curriculum, students will have visual material that they can look at while being taught a new topic. Worksheets can contain homework assignments for the students, as well as sample problems, which helps reinforce the material that was taught. Additionally, by having the homework incorporated on the same sheet as the classroom activity, the students have examples to refer to as they do their homework. If the teachers choose to have the worksheets submitted, they can then evaluate the progress of the students learning as well as how well the information was retained from the classroom.

Familiarizing teachers with MVH software

The MVH software is free online and can be downloaded by the general public. However, some teachers may have trouble acquiring the program from the website and then running it properly. Therefore, it would be beneficial to provide them with the program and review its basic uses. These could include how to import a digital image as well as applying the different light filters in order to analyze the vegetation in the photo. If the teachers are familiar with the program they can easily educate the students about its basic functions. Therefore, we recommend that future teams meet with teachers before programs in order to teach them how to use the software.

Camera Sport mode

Aerial Photography is a great tool for taking detailed pictures of an area because it operates at low altitudes. However, strong winds can cause the camera rigs to swing abruptly in the air. These sudden shifts and turns cause the camera to take blurry pictures. The pictures ought to be fairly clear or else it becomes more difficult to measure the vegetation health. It is important to review all the modes featured on the digital camera that is used because some cameras are able to capture vivid shots in quick movements. Therefore, we recommend using the Sport mode, which can also be called Kids and Pets mode, on the camera, which increases the shutter speed and sensitivity of the camera in order to capture photos of a moving target. This is a very helpful tool because varying winds can often create motion within a picture.

Communication with schools

A difficulty that our group encountered was contacting and receiving timely responses from schools and district officials. Therefore, we recommend that future teams contact teachers and superintendents during the PQP phase of the project. This will allow schools to better incorporate our curriculum into their own. This also gives the schools time to review our material and make any suggestions about specific topics. Since each group of students is learning at different paces, they will be up to different topics and therefore, they may or may not have covered the same material as another group. This variation will affect the curriculum that the teachers are given because we do not want to waste the students' time going over material in which they are already proficient.

Superintendents as well as curriculum directors should be informed of our curriculum a few months beforehand, preferably during the previous school year so they are aware of our program as they plan out the following year's activities. By giving the officials advanced warning, they will be able to apply for grants that would allow districts to pay for the costs of our program, such that they can afford the more expensive equipment rather than having to settle for the cheaper alternative.

Conclusion

In the end, our project has not yet come to fruition, as there is opportunity for another team to come in and pick up where our team has left off. In the future of Near Earth Aerial Tracking at Blue Hill Observatory, we hope that this program continues to grow, becoming well integrated into schools participating in Digital Earth Watch. We have learned over the course of our experience with the Blue Hill Observatory that the implementation of a new curriculum takes a lot of time to be fit into a school's curriculum, and until that time, the program may be most beneficial if used as an after-school activity or summer program, where the program does not interfere with the existing Massachusetts Curriculum Frameworks.

As our team finishes our work with the Blue Hill Observatory, we leave starting points for the next team to come in and inherit this project. The first of these is to shape the curriculum that our team has developed into smaller modules, which can be accessible via the Blue Hill Observatory and online sources. Ideally, through the course of time, these modules may hopefully be published in educational science journals. Another starting point for the next incoming team would be to begin to collect more data from schools, and communicate with organizations such as ESIP (Earth Science Information Partners), with the hope of implementing the data into global research.

Through the natural development of this program, or even through additional IQP projects, our team envisions this program growing into an educational mainstay, with data collected from schools being compiled and used in conjunction with satellite imagery to monitor vegetation health in the Boston area.

Appendix A: Blue Hill Observatory

In 1885, Abbott Lawrence Rotch constructed the Blue Hill Observatory, at the cost of $3,500, with the goal of carrying out a weather observation program, which has gone uninterrupted until this day. On August 4, 1894, five kites were used to lift a thermograph 1400 feet into the air, marking the first use of kites in the observatory's research. In 1912, after the death of Abbott Rotch, the observatory was taken over by Harvard University. Blue Hill Observatory was under ownership of the university until 1971, when Harvard turned the observatory over to the Massachusetts Metropolitan District Commission.

The observatory was named as a national landmark in 1989. In 1999, Blue Hill Observatory underwent an extensive renovation, and the non-profit Blue Hill Observatory Science Center was formed. This organization has expanded the goal of the Blue Hill Observatory, broadening the goal of climate observation to include the spread of interest and understanding of atmospheric science to the surrounding community.

Figure 21. A picture taken by the Blue Hill Observatory/WPI team before Hurricane Earl. *Source: Taken on 3 September 2010 by the WPI team*

The Blue Hill Observatory Science Center heads several weather based programs for students and families that include activities such as tours, field trips and many other projects. Some of these programs offered at the Observatory are kite-making workshops, weather forecasting, and even balloon launches to learn about the wind. Even with the small staff that the

Observatory has, they are still able to run these projects as well as run the observatory's many weather instruments and compile the data.

Today the Blue Hill Observatory is headed by Charles Orloff, who is the Executive Director. The majority of their vegetative data was gathered through the Environmental Picture Post Program. Other than that, they are looking for new methods to gather such data so they can add it to their already extensive weather forecasting and tracking arsenal.

Appendix B: Massachusetts Curriculum Frameworks

Earth and Life Sciences material taken from Massachusetts Department of Education, 2006
Mathematics material taken from Massachusetts Department of Education, 2000

Earth and Space Science

In earth and space science, students study the origin, structure, and physical phenomena of the earth and the universe. Earth and space science studies include concepts in geology, meteorology, oceanography, and astronomy. These studies integrate previously or simultaneously gained understandings in physical and life science with the physical environment. Through the study of earth and space, students learn about the nature and interactions of oceans and the atmosphere, and of earth processes, including plate tectonics, changes in topography over time, and the place of the earth in the universe.

- In **grades PreK–2**, students are naturally interested in everything around them. This curiosity leads them to observe, collect, and record information about the earth and about objects visible in the sky. Teachers should encourage their students' observations without feeling compelled to offer precise scientific reasons for these phenomena. Young children bring these experiences to school and learn to extend and focus their explorations. In the process, they learn to work with tools like magnifiers and simple measuring devices.

  Learning standards for grades PreK–2 fall under the following four subtopics: *Earth's Materials; The Weather; The Sun as a Source of Light and Heat;* and *Periodic Phenomena.*

- In **grades 3–5**, students explore properties of geological materials and how they change. They conduct tests to classify materials by observed properties, make and record sequential observations, note patterns and variations, and look for factors that cause change. Students observe weather phenomena and describe them quantitatively using simple tools. They study the water cycle, including the forms and locations of water. The focus is on having students generate questions, investigate possible solutions, make predictions, and evaluate their conclusions.

  Learning standards for grades 3–5 fall under the following six subtopics: *Rocks and Their Properties; Soil; Weather; The Water Cycle; Earth's History;* and *The Earth in the Solar System.*

- In **grades 6–8**, students gain sophistication and experience in using models, satellite images, and maps to represent and interpret processes and features. In the early part of this grade span, students continue to investigate geological materials' properties and methods of origin. As their experiments become more quantitative, students should begin to recognize that many of the earth's natural events occur because of processes such as heat transfer.

  Students in these grades should recognize the interacting nature of the earth's four major systems: the geosphere, hydrosphere, atmosphere, and biosphere. They should begin to see how the earth's movement affects both the living and nonliving components of the world. Attention shifts from the properties of particular objects toward an understanding of the place of the earth in the solar system and changes in the earth's composition and topography over time. Middle school students grapple with the importance and methods of obtaining direct and indirect evidence to support current thinking. They recognize that new technologies and observations change our explanations about how things in the natural world behave.

Learning standards for grades 6–8 fall under the following five subtopics: *Mapping the Earth; Earth's Structure; Heat Transfer in the Earth System; Earth's History;* and *The Earth in the Solar System.*

- At the **high school** level, students review geological, meteorological, oceanographic, and astronomical data to learn about Earth's matter, energy, processes, and cycles. Through these data they also learn about the origin and evolution of the universe. Students gain knowledge about Earth's internal and external energy sources, local weather and climate, and the dynamics of ocean currents. Students learn about the renewable and non-renewable energy resources of Earth and what impact these have on the environment. Through learning about Earth's processes and cycles, students gain a better understanding of nitrogen and carbon cycles, the rock cycle, and plate tectonics. Students also learn about the origin of the universe and how scientists are currently studying deep space and the solar system.

  High school learning standards fall under the following four subtopics: *Matter and Energy in the Earth System; Energy Resources in the Earth System; Earth Processes and Cycles;* and *The Origin and Evolution of the Universe.*(p. 23-24)

Earth and Space Science, Grades 6–8

Learning Standard	Ideas for Developing Investigations and Learning Experiences
Mapping the Earth	
1. Recognize, interpret, and be able to create models of the earth's common physical features in various mapping representations, including contour maps.	Choose a small area of unpaved, sloping ground in the schoolyard or a park. Create a scale contour map of the area. Include true north and magnetic north.
Earth's Structure	
2. Describe the layers of the earth, including the lithosphere, the hot convecting mantle, and the dense metallic core.	Use a Styrofoam ball and paint to construct a cross-section model of the earth.
Heat Transfer in the Earth System	
3. Differentiate among radiation, conduction, and convection, the three mechanisms by which heat is transferred through the earth's system.	Investigate the movement of a drop of food coloring placed in water, with and without a heat source, and in different positions relative to a heat source.
4. Explain the relationship among the energy provided by the sun, the global patterns of atmospheric movement, and the temperature differences among water, land, and atmosphere.	Note the relationship between global wind patterns and ocean current patterns.
Earth's History	
5. Describe how the movement of the earth's crustal plates causes both slow changes in the earth's surface (e.g., formation of mountains and ocean basins) and rapid ones (e.g., volcanic eruptions and earthquakes).	• Use the Pangaea map to understand plate movement. • Research and map the location of volcanic or earthquake activity. Relate these locations to the locations of the earth's tectonic plates.
6. Describe and give examples of ways in which the earth's surface is built up and torn down by natural processes, including deposition of sediments, rock formation, erosion, and weathering.	• Observe signs of erosion and weathering in local habitats and note seasonal changes. • Visit local sites following storm events and observe changes.

Earth and Space Science, Grades 6–8

Learning Standard	IDEAS FOR DEVELOPING INVESTIGATIONS AND LEARNING EXPERIENCES
Earth's History (cont.)	
7. Explain and give examples of how physical evidence, such as fossils and surface features of glaciation, supports theories that the earth has evolved over geologic time.	Make a timeline showing index fossils. Discuss which of these fossils are actually found in New England. Discuss why some may be missing from local rocks.
The Earth in the Solar System	
8. Recognize that gravity is a force that pulls all things on and near the earth toward the center of the earth. Gravity plays a major role in the formation of the planets, stars, and solar system and in determining their motions.	Observe the speed at which objects of various mass drop from a common height. Use a chronometer to accurately measure time and plot the data as mass versus time necessary to reach the ground.
9. Describe lunar and solar eclipses, the observed moon phases, and tides. Relate them to the relative positions of the earth, moon, and sun.	Use globes and a light source to explain why high tides on two successive mornings are typically about 25 hours (rather than 24) apart.
10. Compare and contrast properties and conditions of objects in the solar system (i.e., sun, planets, and moons) to those on Earth (i.e., gravitational force, distance from the sun, speed, movement, temperature, and atmospheric conditions).	Using light objects such as balloons or basketballs, and heavy objects such as rocks, make models that show how heavy a 1 kg pumpkin would seem on the surfaces of the moon, Mars, Earth, and Jupiter.
11. Explain how the tilt of the earth and its revolution around the sun result in an uneven heating of the earth, which in turn causes the seasons.	
12. Recognize that the universe contains many billions of galaxies, and that each galaxy contains many billions of stars.	Count the number of stars that can be seen with the naked eye in a small group such as the Pleiades. Repeat with low-power binoculars. Repeat again with telescope or powerful binoculars. Research the number of stars present. Discuss the meaning of the research and its results.

Massachusetts Department of Education. (2006). Massachusetts Science and Technology/Engineering Curriculum Framework. Malden, MA: Retrieved April 20, 2010 from http://www.doe.mass.edu/frameworks/current.html (p. 32-33)

Learning Standard	Ideas for Developing Investigations and Learning Experiences
Classification of Organisms	
13. Classify organisms into the currently recognized kingdoms according to characteristics that they share. Be familiar with organisms from each kingdom.	
Structure and Function of Cells	
14. Recognize that all organisms are composed of cells, and that many organisms are single-celled (unicellular), e.g., bacteria, yeast. In these single-celled organisms, one cell must carry out all of the basic functions of life.	Observe, describe, record, and compare a variety of unicellular organisms found in aquatic ecosystems.
15. Compare and contrast plant and animal cells, including major organelles (cell membrane, cell wall, nucleus, cytoplasm, chloroplasts, mitochondria, vacuoles).	Observe a range of plant and animal cells to identify the cell wall, cell membrane, chloroplasts, vacuoles, nucleus, and cytoplasm when present.
16. Recognize that within cells, many of the basic functions of organisms (e.g., extracting energy from food and getting rid of waste) are carried out. The way in which cells function is similar in all living organisms.	
Systems in Living Things	
17. Describe the hierarchical organization of multicellular organisms from cells to tissues to organs to systems to organisms.	
18. Identify the general functions of the major systems of the human body (digestion, respiration, reproduction, circulation, excretion, protection from disease, and movement, control, and coordination) and describe ways that these systems interact with each other.	

Life Science (Biology), Grades 6–8

Learning Standard	Ideas for Developing Investigations and Learning Experiences
Reproduction and Heredity	
19. Recognize that every organism requires a set of instructions that specifies its traits. These instructions are stored in the organism's chromosomes. Heredity is the passage of these instructions from one generation to another.	
20. Recognize that hereditary information is contained in genes located in the chromosomes of each cell. A human cell contains about 30,000 different genes on 23 different chromosomes.	
21. Compare sexual reproduction (offspring inherit half of their genes from each parent) with asexual reproduction (offspring is an identical copy of the parent's cell).	
Evolution and Biodiversity	
22. Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms.	
23. Recognize that evidence drawn from geology, fossils, and comparative anatomy provides the basis of the theory of evolution.	Is the pterodactyl a flying reptile or the ancestor of birds? Discuss both possibilities based on the structural characteristics shown in pterodactyl fossils and those of modern birds and reptiles.
24. Relate the extinction of species to a mismatch of adaptation and the environment.	Relate how numerous species could not adapt to habitat destruction and overkilling by humans, e.g., woolly mammoth, passenger pigeon, great auk.
Living Things and Their Environment	
25. Give examples of ways in which organisms interact and have different functions within an ecosystem that enable the ecosystem to survive.	Study several symbiotic relationships such as oxpecker (bird) with rhinoceros (mammal). Identify specific benefits received by one or both partners.

Life Science (Biology), Grades 6–8

Learning Standard	Ideas for Developing Investigations and Learning Experiences
Energy and Living Things	
26. Explain the roles and relationships among producers, consumers, and decomposers in the process of energy transfer in a food web.	Distribute pictures of various producers, consumers, and decomposers to groups of students. Have each group organize the pictures according to the relationships among the pictured species and write a paragraph that explains the roles and relationships.
27. Explain how dead plants and animals are broken down by other living organisms and how this process contributes to the system as a whole.	Observe decomposer organisms in a compost heap on the school grounds, a compost column in a plastic bottle, or a worm bin. Use compost for starting seeds in the classroom or in a schoolyard garden.
28. Recognize that producers (plants that contain chlorophyll) use the energy from sunlight to make sugars from carbon dioxide and water through a process called photosynthesis. This food can be used immediately, stored for later use, or used by other organisms.	Test for sugars and starch in plant leaves.
Changes in Ecosystems Over Time	
29. Identify ways in which ecosystems have changed throughout geologic time in response to physical conditions, interactions among organisms, and the actions of humans. Describe how changes may be catastrophes such as volcanic eruptions or ice storms.	Study changes in an area of the schoolyard or a local ecosystem over an extended period. Students might even compare their observations to those made by students in previous years.
30. Recognize that biological evolution accounts for the diversity of species developed through gradual processes over many generations.	

Massachusetts Department of Education. (2006). Massachusetts Science and Technology/Engineering Curriculum Framework. Malden, MA: Retrieved April 20, 2010 from http://www.doe.mass.edu/frameworks/current.html (p. 51-53)

Mathematics Learning Standards for Grades 7–8

Number Sense and Operations

Understand numbers, ways of representing numbers, relationships among numbers, and number systems

Understand meanings of operations and how they relate to one another

Compute fluently and make reasonable estimates

Students engage in problem solving, communicating, reasoning, connecting, and representing as they:

8.N.1 Compare, order, estimate, and translate among integers, fractions and mixed numbers (i.e., rational numbers), decimals, and percents.

8.N.2 Define, compare, order, and apply frequently used irrational numbers, such as $\sqrt{2}$ and π.

8.N.3 Use ratios and proportions in the solution of problems, in particular, problems involving unit rates, scale factors, and rate of change.

8.N.4 Represent numbers in scientific notation, and use them in calculations and problem situations.

8.N.5 Apply number theory concepts, including prime factorization and relatively prime numbers, to the solution of problems.

8.N.6 Demonstrate an understanding of absolute value, e.g., $|-3| = |3| = 3$.

8.N.7 Apply the rules of powers and roots to the solution of problems. Extend the Order of Operations to include positive integer exponents and square roots.

8.N.8 Demonstrate an understanding of the properties of arithmetic operations on rational numbers. Use the associative, commutative, and distributive properties; properties of the identity and inverse elements (e.g., $-7 + 7 = 0$; $3/4 \times 4/3 = 1$); and the notion of closure of a subset of the rational numbers under an operation (e.g., the set of odd integers is closed under multiplication but not under addition).

8.N.9 Use the inverse relationships of addition and subtraction, multiplication and division, and squaring and finding square roots to simplify computations and solve problems, e.g. multiplying by 1/2 or 0.5 is the same as dividing by 2.

8.N.10 Estimate and compute with fractions (including simplification of fractions), integers, decimals, and percents (including those greater than 100 and less than 1).

8.N.11 Determine when an estimate rather than an exact answer is appropriate and apply in problem situations.

8.N.12 Select and use appropriate operations—addition, subtraction, multiplication, division, and positive integer exponents—to solve problems with rational numbers (including negatives).

Patterns, Relations, and Algebra

Understand patterns, relations, and functions

Represent and analyze mathematical situations and structures using algebraic symbols

Use mathematical models to represent and understand quantitative relationships

Analyze change in various contexts

Students engage in problem solving, communicating, reasoning, connecting, and representing as they:

8.P.1 Extend, represent, analyze, and generalize a variety of patterns with tables, graphs, words, and, when possible, symbolic expressions. Include arithmetic and geometric progressions, e.g., compounding.

8.P.2 Evaluate simple algebraic expressions for given variable values, e.g., $3a^2 – b$ for a = 3 and b = 7.

8.P.3 Demonstrate an understanding of the identity (-x)(-y) = xy. Use this identity to simplify algebraic expressions, e.g., (-2)(-x+2) = 2x - 4.

8.P.4 Create and use symbolic expressions and relate them to verbal, tabular, and graphical representations.

Patterns, Relations, and Algebra (continued)

8.P.5 Identify the slope of a line as a measure of its steepness and as a constant rate of change from its table of values, equation, or graph. Apply the concept of slope to the solution of problems.

8.P.6 Identify the roles of variables within an equation, e.g., y = mx + b, expressing y as a function of x with parameters m and b.

8.P.7 Set up and solve linear equations and inequalities with one or two variables, using algebraic methods, models, and/or graphs.

8.P.8 Explain and analyze—both quantitatively and qualitatively, using pictures, graphs, charts, or equations—how a change in one variable results in a change in another variable in functional relationships, e.g., $C = \pi d$, $A = \pi r^2$ (A as a function of r), $A_{rectangle} = lw$ ($A_{rectangle}$ as a function of l and w).

8.P.9 Use linear equations to model and analyze problems involving proportional relationships. Use technology as appropriate.

8.P.10 Use tables and graphs to represent and compare linear growth patterns. In particular, compare rates of change and x- and y-intercepts of different linear patterns.

Geometry

Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships

Specify locations and describe spatial relationships using coordinate geometry and other representational systems

Apply transformations and use symmetry to analyze mathematical situations

Use visualization, spatial reasoning, and geometric modeling to solve problems

Students engage in problem solving, communicating, reasoning, connecting, and representing as they:

8.G.1 Analyze, apply, and explain the relationship between the number of sides and the sums of the interior and exterior angle measures of polygons.
8.G.2 Classify figures in terms of congruence and similarity, and apply these relationships to the solution of problems.
8.G.3 Demonstrate an understanding of the relationships of angles formed by intersecting lines, including parallel lines cut by a transversal.
8.G.4 Demonstrate an understanding of the Pythagorean theorem. Apply the theorem to the solution of problems.
8.G.5 Use a straightedge, compass, or other tools to formulate and test conjectures, and to draw geometric figures.

8.G.6 Predict the results of transformations on unmarked or coordinate planes and draw the transformed figure, e.g., predict how tessellations transform under translations, reflections, and rotations.

8.G.7 Identify three-dimensional figures (e.g., prisms, pyramids) by their physical appearance, distinguishing attributes, and spatial relationships such as parallel faces.
8.G.8 Recognize and draw two-dimensional representations of three-dimensional objects, e.g., nets, projections, and perspective drawings.

Measurement

Understand measurable attributes of objects and the units, systems, and processes of measurement

Apply appropriate techniques, tools, and formulas to determine measurements

Students engage in problem solving, communicating, reasoning, connecting, and representing as they:

8.M.1 Select, convert (within the same system of measurement), and use appropriate units of measurement or scale.
8.M.2 Given the formulas, convert from one system of measurement to another. Use technology as appropriate.

8.M.3 Demonstrate an understanding of the concepts and apply formulas and procedures for determining measures, including those of area and perimeter/circumference of parallelograms, trapezoids, and circles. Given the formulas, determine the surface area and volume of rectangular prisms, cylinders, and spheres. Use technology as appropriate.
8.M.4 Use ratio and proportion (including scale factors) in the solution of problems, including problems involving similar plane figures and indirect measurement.
8.M.5 Use models, graphs, and formulas to solve simple problems involving rates, e.g., velocity and density.

Massachusetts Department of Education. (2000). Massachusetts Mathematics Curriculum Framework. Malden, MA: Retrieved April 20, 2010 from http://www.doe.mass.edu/frameworks/current.html (p. 48-50)

Appendix C: Letter to Schools in the Boston Area

The Blue Hill Observatory Science Center in Milton, MA is offering an educational opportunity using Near Earth Aerial Tracking (NEAT). This system includes aerial photography from kites, balloons or remote controlled aircraft. Participating teachers can learn systems to use with students later or we can come to your school or another mutually convenient site to work directly with the students.

There are a wide range of dates available between now and October 14. There are dates available year round but the times and opportunities shrink after October 14. We are working with three Juniors from WPI on curriculum integration and classroom opportunities. These students would love to work directly with students and teachers to help develop ideas and methods. You can see some of the work on our Facebook page: http://www.facebook.com/pages/WPI-Blue-Hills-Observatory-Kite-Aerial-Photography/147989138566681

To book a session or to learn more, please contact Don McCasland, Program Director at Blue Hill Observatory Science Center PO Box 187 Readville MA 02137

617-696-0562 dmccasland@bluehill.org

Appendix D: Cost Benefit Analysis

Businesses often reach a point in their operations where they consider performing actions that significantly influence the present financial or productive nature of the business. As such, it is necessary, or at least sensible, for the business to properly assess the consequences of the decision before it is actually implemented. One effective approach to doing this is a method called cost-benefit analysis. Originating in the 1930s, cost-benefit analysis is the exercise of evaluating a decision or action's consequences by weighing the detriments, or costs, against the profits, or benefits, of the action.

The philosophy behind cost-benefit analysis was first conceived in 1936, with the dam projects of the Works Progress Administration (WPA) in the western United States (Atkins, 2004, pp 114-116). Administered by the federal government, the general policy behind the projects was that they would only be started if the speculated benefits exceeded their accrued costs. The present nature of cost-based analysis is essentially rooted in this basic philosophy.

Cost benefit analysis has a simple goal, to check if initial costs pay off in the long run (Michel & Oliverio, 2007, pp 167- 168). This can be measured in how long the payback period is, or if there even is a payback at all. The complex part of this is that costs change depending upon the needs of the one involved. Our team used the following formula to calculate the Cost Benefit: $Cost\ to\ rent\ our\ program - Cost\ to\ operate\ our\ program = Profit.$ If the result of the equation is positive, then the program is generating income. If the result is negative, the program must be reworked, since it is not collecting a profit.

Appendix E: Lifting Capabilities of Common Gases

Helium		
Diameter Ft.	**Volume Cu. Ft.**	**Lift Lbs.**
1	0.524	0.03
2	4.189	0.27
3	14.14	0.91
4	33.51	2.15
5	65.45	4.19
6	113.1	7.25
7	179.6	11.51
8	268.1	17.18
9	381.7	24.46
10	523.6	33.55
12	904.8	57.97
16	2144.8	137.42

Hydrogen		
Diameter Ft.	**Volume Cu. Ft.**	**Lift Lbs.**
1	0.524	0.04
2	4.189	0.29
3	14.14	0.98
4	33.51	2.33
5	65.45	4.56
6	113.1	7.87
7	179.6	12.50
8	268.1	18.66
9	381.7	26.57
10	523.6	36.45
12	904.8	62.98
16	2144.8	149.29

Natural Gas (Methane)		
Diameter Ft.	**Volume Cu. Ft.**	**Lift Lbs.**
1	0.524	0.02
2	4.189	0.13
3	14.14	0.43
4	33.51	1.02
5	65.45	2.00
6	113.1	3.45
7	179.6	5.49
8	268.1	8.19
9	381.7	11.66
10	523.6	16.00
12	904.8	27.64
16	2144.8	65.52

Appendix F: Generic Kite Information

Kite Type	Wind Speed (0-12 mph)	Lifting Capability per Height of Kite	Ease of Construction	Stability	Angle of Flight
Delta	3-12	Light	Simple	Stable	High Angle
Delta Conyne	4-12 (small) 3-16 (large)	Light	Simple	Very stable	Adjustable
Sled	0-7	Trained together	Basic	Minimal	Moderate
Rokkaku	1-3	Moderate	Requires Practice	Very stable	Adjustable
Diamond	7-15	Moderate	Simple	Stable	Adjustable
Parafoil/Flow Form	3-20	Heavy	None Required	Unstable, may require tails	Low Angle
Box	8-12	High	Practice	VERY Stable	Wind speed dependent

Appendix G: Developed Curriculum, Grades 5-9

The initial project that would be implemented would involve students breaking up into small groups to create their own kites, given a prepared kite-making kit. This kit would include a 48”x48” piece of nylon fabric, varying lengths of wooden dowels, duct tape a pre-spooled reel of appropriate kite string, and a simple camera-mounting rig. Each group of students will come up with their own design for any number of kites that can be made from the given piece of nylon. After each group completes its kite and rig, they will be assigned to a 30’x30’ portion of a greater grid of 30’x30’ areas. The goal of this grid is to have students understand the effect of human existence as they move further away from their school. This will hopefully trigger a classroom discussion and require critical thinking.

Mathematics:

Geometry- Due to the generic size and shape of the given nylon, there are inherently many different designs that can be created out of the nylon. Among these are a rokkaku, a diamond (each of the previous with leftover material to create smaller kites), and multiple varying sizes of Delta kites.

- For the younger students, we can reinforce general geometry, both by describing the shapes of the kites, and by showing students how to create other shapes from the leftover nylon material.
- For the older students, we can begin having the students to calculate the total area of their kite designs, to see which design has the greatest surface area. This allows the students to learn how to optimize the flight capability to their kites.

Sum of Interior Angles-Through the following lesson plans, we aim to reinforce the principles of geometry, basic algebra.

5. Focus on the basic attributes of polygons.

   a. Teach students that there are 180 degrees in a triangle (Delta kite), and that each additional side adds another additional 180 degrees.
6. Begin to integrate multiplication
   a. Introduce the students to the formula (n-2)*180=sum and give them basic problems using the formula
7. Use word problems to implement the previously stated equation.
   a. Using the (n-2)*180 formula, solve word problems with students. Ex- What is the sum of interior angles of a diamond kite? If we turned it into a rokkaku, what is the sum of interior angles now? How much has it been increase by?
8. Walk students through the derivation for the sum formula.
   a. Show the same derivation as with the 9 grade students, but walk through every step with the students
9. Use a basic triangle to derive the formula for the sum of interior angles
   a. Show students that using a basic triangle, you can divide any polygon into the sum of its parts.

Basic Differential Equations- This unit would serve to reinforce the principles of addition, subtraction, multiplication and division, while providing word problems to help students' critical thinking skills. The use of these problems at higher levels also reinforces fractions, decimals, and percentages.

5. Present basic math problems in the form of word problems
   i. For example, if a balloon can hold 100 cubic feet, and 20 of it empties overnight, how much is left?
6. Begin to introduce a multi-step problem
   i. If the balloon holds 100 cubic feet, and it loses 20 every night, how much is left after 3 days?
7. Provided a graph of the deflation of the balloon, have students develop an understanding of deflation v. time
8. Provide students with data, from which a linear deflation curve can be generated, using y = mx+b

        i. Ask students to extrapolate data from the curve they've generated.

9. Introduce non-linear deflation
    i. If the balloon can carry 100 cubic feet, and 5% of the remainder empties every night, how much is left over after X nights? What percent is left over?

Relating Degrees to Cardinal Directions- while during fieldwork we can teach students how rotation changes their coordination on a map (relating to earth sciences)

As an example, we could have the students stand facing north, and ask them to rotate their orientation 90 degrees to the right, and ask them which direction they are now facing, and vice versa.

Science and Engineering:

Life Sciences- This lesson plan will educate students about the practical methods that can be used to measure health in vegetation.

- After each group of students takes pictures of their respective areas, the pictures can then be run through infrared and LANDSAT image filters, available on the Measuring Vegetation Health website. After this has been done, students can determine the health of the plant life in their area, and compare it with that of other groups. Through this, students may be able to determine how human presence affects the health of plant life.
    - Provide examples of this. For example, why are the trees near the roads less healthy than those that are further away? (Road salt runoff)
- Over the course of the program, students can "identify ways in which ecosystems have changed throughout geologic time in response to physical conditions,…, and the actions of humans." (Massachusetts Curriculum Frameworks, p. 53)
- With the images that the students have taken, we may identify the types of plants in the area, classifying them by genus, species and phylum.

Earth Sciences- This section will cover the students' ability to analyze data by means of mapping and scaling sets.

- By assigning the student's a single pixel on a satellite image, which relates to a 30'x30' land area, students can practice the scaling that is present on maps.
- Students can get a better understanding of wind patterns of the eastern seaboard, in addition to learn differences between wind patterns at ground level compared to at flying altitudes.

Scientific Method- This unit will show the students the necessary steps to conduct an experiment.

1. Ask a question
    a. Is the vegetation around "School X" healthy?
2. Do Research
    a. Find out the history of the area
3. Develop a Hypothesis
    a. "Group X" believes that the amount of human action in the area has lessened the health of the environment
4. Test with an Experiment
    a. Kite Aerial Photography followed by LANDSAT and infrared viewing
5. Analyze Results
    a. Students will analyze what they have found about their area and discuss with their classmates what they have found.
6. Draw a conclusion
    a. Is the vegetation healthy or not?

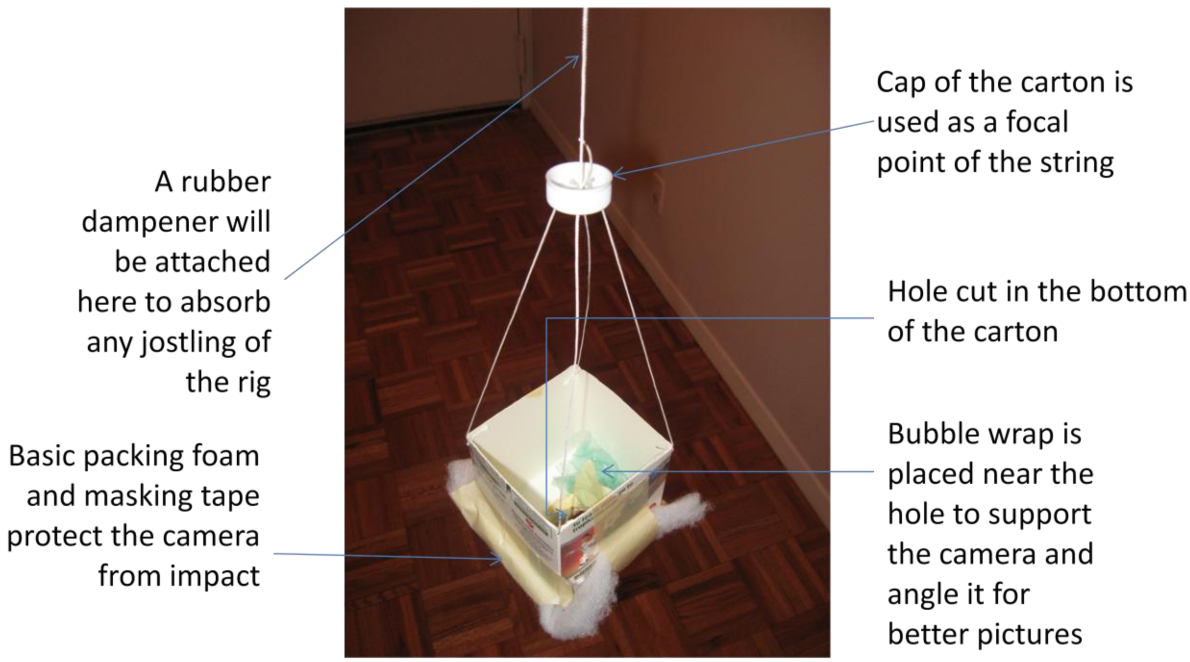
Engineering- This section will introduce students in applying science and mathematics in order to solve real solutions. The activity that we plan on giving to the students will cause the teams to use critical thinking skills in order to determine the best design for their kites. The problem solving skills that we aim to teach the students are the very roots of engineering.

- **Kites-** the students will be engineering their own kites from the given material. In order to do so, they will be given a list of options. From there, it is up to the students to determine which kite will suit them better. After flying, students will discuss in class what made each kite better than the next (style, surface area, number of kite, amount of kite line)
- **Camera Rig**- in addition to building their own kites, students will engineer their own homemade camera rig, from common everyday materials, such as milk containers, bottle caps, and string. Once again, there will be a discussion held after flying to reason about which rig is better.

Technology- This lesson plan will guide the students through understanding the software that is used for accessing satellite images and applying filters in order to measure vegetative health. The section will also cover the development of features used by digital camera and the rigs that they are attached to.

- **Computer Programs**- the students will be responsible for becoming familiar with the computer programs on the MVH/DEW website. Students will learn how to take the images that they've taken with their cameras, and run them through different light filters, like LANDSAT and infrared (both of which are available on the MVH website.)
- **Camera-** The students will learn about the different modes of the cameras they will be working with. For the most part, students will be learning to use the Canon A560. Among other things, students will learn how to set the focus of the camera to infinity, learn the difference between optical and digital zoom, and learn about aperture and exposure.
- **Camera Rig**- We will familiarize the students with the camera rig that we use, the Brooxes rig. We are going to be teaching the students about the functionality of our rig, including the details of the remote control and the servos, and how they relate to the pan, tilt, and shutter release.

Appendix H : Homemade Kite Aerial Photography Rig



Appendix I: Sample Lesson Plan for Middle School Visit

Introduction

- Introduce topic and purpose of project

Kite Making and Associated Math: 75 – 90 minutes

- Split students into seven groups of two
- Show the two types of kites that the students can choose from
- List Materials needed to make each kite
    - Rokkaku
        - 3 spars
        - 1 Piece of fabric
        - 1 Roll of duct tape
        - 1 pair of scissors
        - 1 spool of kite line
    - Diamond
        - 2 spars
        - 1 piece of fabric
        - 1 Roll of duct tape
        - 1 pair of scissors
        - 1 spool of kite line
- List the necessary instructions to make each kite
    - Rokkaku
        - Lay our piece of fabric
        - Fold fabric in half
        - Draw a straight line from each inner corner that touches the opposite side so as to from a symmetrical trapezoid

            - Ensure that the ratio of the triangular heights to the overall height is no more than 1:5 and no less than 1:4
    - Diamond
        - Lay out piece of fabric
        - Fold fabric in half
        - Draw 2 straight lines from each outer corner that connect on the other side
            - Ensure that the ratio of the two lengths from that point is no more than 1:5 and no less than 1:4
- Apply mathematics associated with activity
    - Ratios
        - Distance from top of kite, aspect ratio
        - Show difference between 1:4 and ¼
    - Geometry
        - Shapes
            - Triangles to Rectangles to Trapezoids
        - Symmetry
            - Symmetrical Shapes
            - Asymmetrical Shapes
        - Angles
            - Sum of Interior Angles
            - 180(n-2) = Total Interior Angle
        - Surface Area
            - L*W = Area of Rectangle/Square
            - ½*L*W*H = Area of Triangle
            - ½*H* (B_1+ B_2) = Area of Trapezoid
                - Show Derivation of this formula in particular

Kite Flying and Aerial Photography: 45 – 75 minutes

- Go over mechanics of kite flying
    - One student will hold the kite at launch while the other holds onto the reel

    - Once the kite is up, the student not flying will be taking notes on the kite's behavior in general as well as compared to the rest of the other groups.
    - The students will switch roles in the middle of their flight so that both will be able to experience flying as well as being able to have two sets of notes.
- Show how to control the line of the reel
- Take pictures from own premade camera rig
- Display pictures taken from camera

Analysis: 30 – 60 minutes

- Go over what was done in the previous activities
    - Discuss why the students' kites were flying better or worse, what could they have changed to make theirs fly better?
        - Surface area
        - Quality of work
        - Bowing of spars
        - Style of kite
        - Kite flying skill
- Critical Thinking/ Class Discussion

Survey: 20 – 40 minutes

- Distribute Curriculum Matrix/ Survey

Appendix J: Environmental Lesson Plan

Introduction – 5 minutes

- Introduce group and purpose of lesson plan
- MVH and its involvement in Environmental Science

KAP vs. Satellite – 10 minutes

- Detail/Resolution
  - KAP pictures allow for students to view specific areas and trees
  - Satellite images allow for students to analyze a general area, but not specific plants and species
- Availability of images (reliant on equipment)
  - Satellite Imagery only changes over long periods of time, usually 6 months which skips seasons.
  - KAP images can be taken whenever necessary and over periods of time to show changes throughout seasons as well as transitions.
- Angle of images
  - Kite Aerial Photography can provide images as a landscape or straight down
  - Other options generally provide minimal sideways views

Plant Stress Detection filters – 20-30 minutes

- Importing original pictures
  - Photos used in this session will be provided by our group from previous programs.
- Discuss what can be shown in original
  - How can students tell whether vegetation in the original image is healthy?
    - Look for discoloration such as changing colors from the changing seasons, or dying plant life
- Adjusting color schemes
  - Set blue and green colors to “infrared” and red portions to “red”
- Discuss what is shown through the filtering
  - Can the students make inferences based off the original image as to what the colors in the light filter mean?

- After we explain the meaning of the light filters, what can students learn from the images?
    - Health of the vegetation
    - Range of species in the area

Analysis – If time permits

- Individual work
    - Have students view a set of pictures and come up with observations about the pictures, and potential reasons for what they are viewing
- Group analysis
    - Allow the students to discuss their opinions on what they are seeing in the pictures.
    - What theories exists as to why specific events are occurring.
- Cover previous activities

Appendix K: Data Collection Matrix

	How difficult did you find this subject to be?	How Interested were you in the material?	How much did you learn about this subject?	How well was this material presented?	Was there enough communication with the advisors?
Life Science					
Earth Science					
Geometry					
Algebra					
Engineering					

Appendix L: Quiz Provided to Students by the Blue Hill Observatory

Kite Activity Review

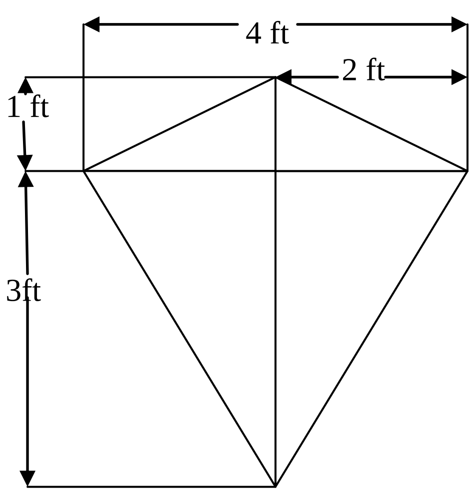
(N-2) * 180 = Sum of Interior Angles

1. If N=11, what is the sum of the interior angles?

2. If the sum of interior angles is 900̊, how many sides does the polygon have?

3. For every 100 ft. of line that is let out, 70 ft. of altitude is gained. If 250 ft. of line is let out, how much altitude has been gained?

4. Surface Area (Diamond Kite with diagram)



Using the diagram above, calculate the total area of this diamond shaped kite.

What is the aspect ratio of the kite, or the ratio of the length from the top of the kite to the spreader in relation to the entire length of the kite?

5. A right triangle has side a=5 and size b=12. If $a^2 + b^2 = c^2$, what is size c equal to?

6. What did we do the kite to catch more wind?

7. What were the three items that we controlled from the remote control?

8. What are the three types of sciences that we can learn from kite aerial photography?

9. Why is kite aerial photography useful for society?

Appendix M: Data Collection Matrix Results from Greenfield, MA

The numbers are based on each students answer for each question. Each row should add up to 15.

Q. How difficult did you find this subject to be?

	Easy	Somewhat Difficult	Hard
Life Science	8	1	6
Earth Science	9	2	4
Geometry	10	4	1
Algebra	8	2	5
Engineering	11	4	0

Q. How interested were you in the Material

	Not	Somewhat	Very
Life Science	4	8	3
Earth Science	4	7	4
Geometry	5	5	5
Algebra	3	8	4
Engineering	0	2	13

Q. How much did you learn about this subject?

	Nothing	A little	A lot
Life Science	3	6	6
Earth Science	4	6	5
Geometry	4	4	7
Algebra	3	4	8
Engineering	0	2	13

Q. How well was this material presented?

	Unclear	Somewhat confusing	Clearly
Life Science	3	4	8
Earth Science	1	4	10
Geometry	0	6	9
Algebra	0	6	9
Engineering	0	4	11

Q. Was there enough communication with the advisors?

	No	In between	Yes
Life Science	1	4	10
Earth Science	0	5	10
Geometry	2	3	10
Algebra	2	1	12
Engineering	2	3	10

Appendix N: Curriculum Modules

Kite Design and Associated Math

- Split students into groups of two
- Show the types of kites that the students can choose from:
    - Rokkaku
    - Delta
    - Diamond
- Talk about how to design each kite as well as the materials required
    - If time permits talk about each kite, most likely one type will need to be chosen in order to fit this activity into a single period.
- Design of each kite
    - Rokkaku
        - Ratios
            - Aspect Ratio- Distance from top of kite to the spreader bar vs. the width of the kite
            - Show difference between 1:4 and ¼
        - Geometry
            - Shapes
                - Triangles
                - Rectangles/Squares
                - Trapezoids
            - Symmetry
                - Symmetrical Shapes
                    - Equilateral Triangles
                    - Isosceles Triangles
                - Asymmetrical Shapes
                    - Right triangle that is not isosceles
                    - Many other configurations
                - Explain how having a symmetrical shaped kite is ideal
                    - Engineering point of view, if one side is larger than the other then the kite will catch more air on that side and will become very unstable and will not be able to sustain flight
                    - With both sides of the kite the same, the kite will not spiral out of control
            - Congruent Shapes

            - All corresponding angles as well as sides have the same dimensions
            - For the kite both the left and right side should be congruent triangles
        - Angles
            - Sum of Interior Angles
            - 180(n-2) = Total Interior Angle
            - Show how the angles at the top and bottom of the kite are related to the aspect ratio of the kite
                - More obtuse, the smaller the aspect ratio
                - More acute, the larger the aspect ratio
            - Bridle angle must be correct in order to control the kite correctly
        - Surface Area
            - L*W = Area of Rectangle/Square
            - ½*L*W*H = Area of Triangle
            - ½*H* $(B_1 + B_2)$ = Area of Trapezoid
                - Show Derivation of this formula in particular
- Delta
    - Geometry
        - Shape
            - Triangle
        - Symmetry
            - Symmetrical Shapes
                - Equilateral Triangles
                - Isosceles Triangles
            - Asymmetrical Shapes
                - Right triangle that is not isosceles
                - Many other configurations
            - Explain how having a symmetrical shaped kite is ideal
                - Engineering point of view, if one side is larger than the other then the kite will catch more air on that side and will become very unstable and will not be able to sustain flight
                - With both sides of the kite the same, the kite will not spiral out of control
        - Similar Shapes
            - Show how the entire delta kite is similar to the triangle formed by the upper portion of the kite using the spreader as the base

        - Properties of similar shapes
            - All corresponding angles are the same size
            - All corresponding sides are proportional by the same factor
    - Angles
        - Sum of Interior Angles
        - 180(n-2) = Total Interior Angle
            - Triangular shape of the Delta makes a nice first example to introduce this topic
        - Show how an isosceles triangle with an obtuse vertex is the favorable shape for a delta kite
            - Wing span is greater which makes a more stable kite
            - More lifting power with a wider wing span
        - Bridle angle must be correct in order to control the kite correctly
    - Surface Area
        - ½*L*W*H = Area of Triangle
        - Greater surface area means greater lift
-
- Diamond
    - Ratios
        - Aspect Ratio- Distance from top of kite to the spreader bar vs the width of the kite
        - Show difference between 1:4 and ¼
    - Geometry
        - Shapes
            - Triangles
        - Symmetry
            - Symmetrical Shapes
                - Equilateral Triangles
                - Isosceles Triangles
            - Asymmetrical Shapes
                - Right triangle that is not isosceles
                - Many other configurations
            - Explain how having a symmetrical shaped kite is ideal
                - Engineering point of view, if one side is larger than the other then the kite will catch more air on that side and will become very unstable and will not be able to sustain flight

        - With both sides of the kite the same, the kite will not spiral out of control
    - Congruent Shapes
        - All corresponding angles as well as sides have the same dimensions
        - For the kite both the left and right side should be congruent triangles
    - Angles
        - Sum of Interior Angles
        - 180(n-2) = Total Interior Angle
        - Show how the angles at the top and bottom of the kite are related to the aspect ratio of the kite
            - More obtuse, the smaller the aspect ratio
            - More acute, the larger the aspect ratio
        - Bridle angle must be correct in order to control the kite correctly
    - Surface Area
        - ½*L*W*H = Area of Triangle
        - Greater surface area means greater lift
- Once the basic design for the kite has been discussed, have the students draw out their own designs for their own kites. Ensure there is variation in the aspect ratios of the kites.
- Collect these designs and save them for the next activity which is the Kite Building Activity.

Kite Building Activity
Break the students into the same groups as the Kite Design lesson

Recap the different types of kites that they will be creating and distribute their designs back to them

Ensure there is enough floor space for the students to work as they construct their kites.

- List Materials needed to make each kite per student
  - Rokkaku
    - 3 spars
    - 1 Piece of fabric
    - 1 Roll of duct tape
    - 1 pair of scissors
    - 1 spool of kite line
  - Delta
    - 4 spars
    - ½ piece of fabric
    - 1 roll of duct tape
    - 1 pair of scissors
    - 1 spool of kite line
  - Diamond
    - 2 spars
    - 1 piece of fabric
    - 1 Roll of duct tape
    - 1 pair of scissors
    - 1 spool of kite line
- List of necessary instructions to make each kite
  - Rokkaku
    - Lay out piece of fabric
    - Fold fabric in half
    - Draw a straight line from each inner corner that touches the opposite side so as to from a symmetrical trapezoid
      - Ensure that the ratio of the triangular heights to the overall height is no more than 1:5 and no less than 1:4
    - Cut along the drawn lines to complete the sail of the kite.
    - Go over how to construct the pockets that will hold the spreader spars in place.
      - Take a 2” piece of duct tape and fold it in half along its 2” length so there is no adhesive exposed.

            - Lay that on a spar where it will be positioned on the kite. Take a piece of duct tape twice that length and tape over the original piece while it is covering the spar so the spar is not caught by this new piece of tape.
            - Fold over the other end so that it is secured to the kite sail.
            - Secure the spine of the kite with tape so it cannot be taken out
            - Attach the bridle by having the lines attached around the spars so the fabric will not be torn. Poke the holes as close to the spars as possible so the line is snug very tightly to the spar.
            - Use a larks head loop for when you attach the bridle to the main kite line.
    - Delta
        - Lay out piece of fabric
        - Fold fabric in half
        - Draw a straight line from one corner to the opposite one to form 2 triangles
            - In this way, 2 delta kites can be made from one piece of fabric so 2 students can use the same piece
        - Cut along the drawn lines to complete the sail of the kite.
        - Go over how to construct the pockets that will hold the spreader spars in place.
            - Take a 2" piece of duct tape and fold it in half along its 2" length so there is no adhesive exposed.
            - Lay that on a spar where it will be positioned on the kite. Take a piece of duct tape twice that length and tape over the original piece while it is covering the spar so the spar is not caught by this new piece of tape.
            - Fold over the other end so that it is secured to the kite sail.
            - Secure the spine of the kite with tape so it cannot be taken out
            - Attach the bridle by having the lines attached around the spars so the fabric will not be torn. Poke the holes as close to the spars as possible so the line is snug very tightly to the spar.
            - Use a larks head loop for when you attach the bridle to the main kite line.
    - Diamond
        - Lay out piece of fabric
        - Fold fabric in half
        - Draw 2 straight lines from each outer corner that connect on the other side
            - Ensure that the ratio of the two lengths from that point is no more than 1:5 and no less than 1:4

        - Cut along the drawn lines to complete the sail of the kite.
        - Go over how to construct the pockets that will hold the spreader spars in place.
            - Take a 2” piece of duct tape and fold it in half along its 2” length so there is no adhesive exposed.
            - Lay that on a spar where it will be positioned on the kite. Take a piece of duct tape twice that length and tape over the original piece while it is covering the spar so the spar is not caught by this new piece of tape.
            - Fold over the other end so that it is secured to the kite sail.
            - Secure the spine of the kite with tape so it cannot be taken out
            - Attach the bridle by having the lines attached around the spars so the fabric will not be torn. Poke the holes as close to the spars as possible so the line is snug very tightly to the spar.
            - Use a larks head loop for when you attach the bridle to the main kite line.

Kite Flying and Aerial Photography

- Go over mechanics of kite flying
    - One kid will hold the kite at launch while the other holds onto the reel
        - Students will learn to be attentive to wind conditions and run directly into the wind.
    - Once the kite is up, the student not flying will be taking notes on the kite’s behavior in general as well as compared to the rest of the other groups.
        - What direction is the kite flying in?
        - How does the wind strength affect the height of the kite?
        - How does the wind affect the flight angle?
    - The students will switch roles in the middle of their flight so that both will be able to experience flying as well as being able to have two sets of notes.
- Show how to control the line of the reel
    - If the wind dies, students learn to work the line to keep the kite afloat
        - “pumping” the line
- Take pictures from own premade camera rig

Technology module
Remote Control

- Instructors perform a lesson on remote controls
  - Introduce channels to students
    - Mention that a channel refers to the number of functions your remote can control.
  - Go over frequency modulation. This describes the mode of transmission of radio signal from transmitter to receiver.
    - Explain that the transmitter and receiver must have the same frequency
  - Mention Nickel Cadmium batteries. These rechargeable batteries are typically used as power for radio transmitters and receivers.
  - Show the students how to use the remote control to work with the camera rig.
    - The left trigger's vertical motions control the tilting
    - The left trigger's horizontal motions control the panning
    - The right trigger's vertical motions control the shutter button which takes the picture

Camera Rig

- Instructors hang the camera rig in view of students to demonstrate what the remote is controlling.
- Go over the components of the camera rig with the students
  - A servo is an electro-mechanical device which moves at fixed angles when it receives a signal from the controller.
    - Show the students where the servos are located on the rig and discuss their functions
  - The receiver is the radio unit on the rig which receives the transmitter signal and relays the control to the servos.
    - Present the receiver attached to the rig
  - Introduce student to the designs and concepts of the Brooxes rigs.
    - Show all of the rigs designed by Brooke Leffler
  - Automated rigs rotate horizontally at small angles in fixed intervals. The rigs continuously rotate and take pictures until the camera runs out of memory or battery power.
  - Mention that a screw is used to fasten the camera to the rig so that it remains in the same position to take the pictures.
  - Present the rig and mention that some camera rigs have carbon legs that are attached at the bottom of the rig. They help to protect the camera rig from any impact.

Camera Modes and Features

- Instructors lead a lecture on digital cameras and the modes and features that are useful for aerial photography
  - Sports mode increases shutter speed in order to increase the chances of stopping the main action of the shot.
  - Therefore, this feature will help to prevent blurriness when the camera is jostling in the air.
  - The Canon PowerShot digital cameras can be hacked and programmed to take automatic pictures on a set interval.
    - Mention that the information of the hacks can be accessed on the CHDK (Canon Hack Development Kit) wikia page
  - Infinity mode is a camera setting that overrides the automatic focusing. It allows landscapes and distant objects to come out as sharp and detailed images.
  - The cameras have to be adjusted to a setting in which they do not go to sleep so that the pictures can be taken during the entire length of the picture period.

MVH module
Satellite/NEAT overview

- Allow students to use Google Earth to view the satellite coverage of the school area
- Instruct students to view NEAT photos of the school area
- Instruct students to brainstorm and make comparisons of the two aerial types in charts or tables
- Discuss the comparisons and any other information that the students did not mention
    - Detail/Resolution
        - How clear are the objects on the ground?
            - KAP pictures allow for students to view specific areas and trees
            - Satellite images allow for students to analyze a general area, but not specific plants and species
    - Availability of images
        - How often are these images taken?
            - Satellite Imagery only changes over long periods of time, usually 6 months which skips seasons.
            - KAP images can be taken whenever necessary and over periods of time to show changes throughout seasons as well as transitions.
    - Angle of images
        - What types of angles are shown from the picture?
            - Kite Aerial Photography can provide images as a landscape or straight down
            - Other options generally provide minimal sideways views

Tri-Color Lighting System

- Show students that there are three primary colors (red, green and blue) used in television, monitor display and digital cameras
    - What is the RGB color model and why is it useful?
        - The model is for the sensing, representation, and display of images in electronic systems
- Introduce the Tri-color software to the students and instruct them to mix around with the primary colors in order to create new ones
    - What colors can be made by altering these light intensities or mixing these two colors?
        - By adjusting and mixing the light intensities of the three primary colors, you are able to produce all the basic colors along with a myriad of others

Plant Stress Detection filters

- Familiarize students with the concept of the electromagnetic spectrum and how infrared is adjacent to the visible part of the spectrum
    - Infrared identifies light that is invisible to the human eye
- Importing original pictures
    - Photos used in this session will be provided by our group from previous programs.
- Discuss what can be shown in original
    - How can students tell whether vegetation in the original image is healthy?
        - Look for discoloration such as changing colors from the changing seasons, or dying plant life
- Introduce the Digital Image Basics program and instruct students to use the false color image to apply the infrared filtering
    - False color image filters the picture to show the intensities of live and dead objects
- Instruct the students to adjust the color schemes of the original photo
    - Set blue and green colors to “infrared” and red portions to “red”
- Discuss what is shown through the filtering
    - Can the students make inferences based off the original image as to what the colors in the light filter mean?
    - After we explain the meaning of the light filters, what can students learn from the images?
        - Health of the vegetation
        - Range of species in the area

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