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# FUTURE ENGINEERS IN WORCESTER PUBLIC SCHOOLS

An Interactive Qualifying Project Report

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by

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# Table of Contents

## Abstract

This paper focuses on the impact and sustainability of the engineering club at Burncoat High School, one of five such programs implemented in Worcester public high schools to cultivate interest in engineering, mathematics, and science. It is our conclusion that this club fulfills an invaluable role to aspiring engineers and scientists in providing a plethora of information in technical career pursuits otherwise not available through typical curriculum, and as such the project should continue and be expanded.

## Acknowledgements

We would like to thank Professor William M. Clark, our project advisor for the Burncoat High School Engineering club, along with the team of additional advisors for each club project location in the city of Worcester. The additional advisors and their respective schools are as follows: Professor Robert E. Connors, North High School; Professor Stephen N. Jasperson, South High School; Professor Thomas H. Keil, Worcester Technical High School; and Professor Kenneth A. Stafford, Doherty High School.

We would especially like to thank our faculty advisor at Burncoat High School, Mr. Michael Juneau for his enthusiasm for keeping the club running for another year. It is his sincere interest in the futures of his students that allows us to continually develop the after school program, draw in new participants, and maintain a superior working relationship with the school administration.

Last, we would like to thank Amanda Cox for putting forth a tremendous effort organizing the program cluster of all five projects this year. Without her insight gained from last year's project experience, and her dedicated efforts coordinating the personnel, the future scientists and engineers club projects may not have happened this year.

# Introduction

## *Project Goals*

The goal of this project was to present various aspects of the engineering curriculum and world to tenth and eleventh graders as they begin to think about their options after high school. In achieving this goal, we hoped to spark and cultivate interest in engineering subject areas not typically available in high school courses. In introducing and promoting these technical fields, we aimed to show that engineering is much more than the stereotypical view of robots and Computer Aided Drafting or Computer Aided Manufacturing (CAD/CAM) models, but instead reaches into every aspect of life and numerous disciplines of study. A secondary goal was to promote higher education and show that classroom learning does relate to and have practical applications in life, and that engineering can be fun, fascinating, and rewarding (both monetarily and otherwise). It can be assumed that lack of knowledge is a main barrier in a technical pursuit, and this project will hopefully lower this barrier.

## *Project Background*

A group of eleven Worcester Polytechnic Institute (WPI) students, working in teams of two or three embarked on related individual projects of creating and maintaining science and engineering clubs at five Worcester public schools, North High School, South High School, Burncoat School, Doherty High School, and Worcester Technical High School. The main objective of these projects was to cultivate interest in engineering, mathematics, and science; this included both introducing students to the disciplines and retaining the students already interested in the matter.  Although the overall objective of each of these club projects was the same, each team faced different challenges presented by their school and as such, it was decided each club would be run independently from one another, with occasional collaborative meetings amongst the team members themselves to share successful strategies and collaborate towards planning one large excursion to WPI with all five schools participating.

The project stemmed from a survey given to all eleventh graders in the Worcester school system indicating that not all the candidates interested in technical fields utilized the Engineering and Technology Academy at Doherty High.  In response to this survey, past student projects suggested possible solutions to meet the needs of these students interested in science and engineering, and evolved as varying degrees of support were received from the school system.

Originally approached by the Advisory Committee on the Status of Women in Worcester, an earlier student project developed and administered a career aspiration survey in the Worcester school system.  After the survey, preliminary projects were originally proposed as a way of identifying an interested pool of students who would then be "coached" by WPI students in conjunction with the school guidance departments to further develop and nurture mathematics, science, and engineering interests.  However, this approach met much opposition due to controversy surrounding the survey content, and the feasibility of the coaching style as presented, and the project goal evolved into a faculty-advised club.  With little time left in the school year, the club project was run as a pilot program in Doherty High School (Dorchik & Duncan, 2006).  Last year’s students built upon the previous work and expanded the pilot program to reach the five high schools, with varying degrees of success in actually starting up the after school programs.  In particular, the project group at Burncoat High School held five after school club meetings, meeting more frequently than once a week, and participated in the

Space Conference at WPI, a series of presentations from WPI student projects. (DeLuca & Fradella, Future Scientists and Engineers Club, 2007) Basically, this current project is a third generation extension and revamping of a project examining aspirations of students in the Worcester Public School system. The first group gauged the feasibility of starting a club, and attempted a pilot program; the second-year groups expanded the pilot program and ran the clubs in five Worcester high schools; and the third-year groups ran the engineering clubs for a prolonged period and looked at club sustainability and impact.

## *Burncoat High School*

Despite Burncoat High School being known for having a strong arts program, it is expanding to incorporate more technical interests, as it now hosts a robotics club and a new course entitled, "Engineering," in addition to the basic math and science courses offered. The 2006-2007 project team composed of Eric DeLuca and Charles Fradella worked on the future engineers club at Burncoat High School in the last academic year. The expansion of the original pilot program to this new location brought many challenges both finding contact personnel and facing time restraints, as discussed in their reported findings (DeLuca & Fradella, Future Scientists and Engineers Club, 2007). Eventually a WPI alumnus, and current Burncoat mathematics and physics teacher, by the name of Michael Juneau heard of the project and embraced the opportunity whole-heartedly, agreeing to be the faculty advisor at the school. Receiving the principal's approval for the project initiative and finding the faculty advisor were major steps towards making the club a reality, however with so much of the time poured into these preliminary steps, there was little time left for the implementation of the project. The "Future Scientists and Engineers Club" at Burncoat High met five times over the span of less than a month at the school and participated in the Space Conference day at WPI, coordinated by Professor John Wilkes, showcasing various student projects relating to space initiatives and possibilities. Although the time spent implementing the club meeting was fairly short, it did establish a presence for the engineering club and left the students in want of more club meetings in the next (2007-2008) year.

Unfortunately, Burncoat High School's 2006-2007 "report card" of information required by the No Child Left Behind Act reveals a dip a Massachusetts Comprehensive Assessment System (MCAS) scores. In both mathematics and language arts, the percentage of students in "Proficient" and "Advanced" placements dropped and the number in "Needs Improvement" and "Warning/Failing" increased from 2005. The full report card with teacher qualifications, student achievement on the MCAS, and school/district accountability is available through Worcester Public Schools (Worcester Public Schools, 2006). The enrollment statistics and "indicators" for Burncoat are slightly alarming to read, as the in-school and out-of-school suspension rates hover around the 25% mark, approximately doubling the district average and four-to-six-fold the state average in each category. Burncoat also shows lack-luster performances below both the state and district averages in graduation rate, and higher averages of absenteeism and dropout rates. Other slight disadvantages to the school include slightly higher averages in student to teacher ratio and students per modern computer. Refer to Appendix 1 for further details about the Enrollment/Indicators for Burncoat High published by the Massachusetts Department of Elementary and Secondary Education (Massachusetts Department of Elementary & Secondary Education). Despite the indicators portraying less than desirable statistics in the previously mentioned assessment areas, Burncoat did show a higher than district (but still lower than the state of Massachusetts) average in the percentage of students planning on attending four year colleges. It was on this hope for continuing education that this project was anticipated to thrive.

## *Problem Overview*

Throughout the twentieth century, American culture has seen a general push towards equal rights of all people with disregard to race, sex, and wealth. Equal opportunity has spread as far as employment, property, financing, and most importantly education. However, even with today's infinite opportunity, there are still definite trends in career path choice with respect to gender, socioeconomic class, and race. It is the intent of this project to break the stereotypical view of engineering and introduce engineering as a viable career option.

Recently, the highest in-demand areas of study for college graduates have been technology-related and business degrees, with engineering majors showing continual annual increases (Byko, 2001). Within the continually growing need for engineers, there lies a desire and need for more female engineers. Despite the slight advantage of females comprising 57% of college graduates, the field of engineering still remains male-dominated (Marklein, 2005), including the faculty and students of most engineering colleges and universities (Landers, 2007).

This demand for more females entering the engineering field is being driven by research suggestions, such as those by Macdonell-Laeser, showing that engaging more females may pose significant benefits to the engineering community. Since creativity varies greatly for everyone and is often different between males and females, and the results of engineering tasks are largely influenced by personal creativity, increasing the female workforce in engineering may indeed unleash a wider array of solutions which may lead to new elements to modern materials, products, and structures (Macdonell-Laeser & Moskal, 2001).

This project was executed with the intent of delving into this presumption by regularly visiting a Worcester public high school and creating a hands-on after school club directed towards science and engineering. The overall goal of the project is twofold: to advertise a science club and observe the types of people interested, and then try to spark a real interest in a technical career after high school for female students.

## Planning

After some deliberation amongst the five teams of WPI students contributing to the 2007-2008 Worcester schools project, it was determined that each team would manage a school club independently. This approach would allow the high school students to become more familiar and comfortable with the presenters. These consistent appearances lend themselves more towards forming a mentorship instead of merely weekly seminars from a variety of different people.

The initial meeting with the high school faculty advisor, Mr. Juneau, further enlightened us as to what last year's presenters, Matthew Duncan and Brian Dorchik, did with the club program. He shared some of the strategies that worked well and suggested possible improvements to the program both in specific instances and in the overall program. Under Mr. Juneau's suggestion, we created two flyers, shown in Appendix 2, for the school. One was to be distributed by science teachers and posted in the halls and a second, more formal flyer was available for students who expressed interest in the program. This flyer also provided a little background about the club and WPI's connection with the club. It was imperative that these flyers be created as soon as possible since they needed to be approved by the school administration before being distributed.

Before creating the flyers we attempted to create a list of the possible meeting topics to be covered throughout the club year. We decided that having an idea list was a solid start, but that the club members' interests and past experiences with clubs and projects might tend to sway the meeting topics. Because of this, we created the flyers based on a few of the ideas, and left topic possibilities open for changing interest levels. The possible areas of interest were to be assessed informally at the first meeting, after a few meetings, and again at the final meeting.

While each small team of WPI students was working to continually develop the engineering club at their respective school, we were attempting to organize a large group field trip to the WPI campus. Similar to last year, each of the five school groups would attend on the same day and receive a tour of the campus and an admissions talk. Unlike last year, however, the students would not be expected to attend Interactive Qualifying Project presentations, as we received feedback from both students and faculty that these talks were dry and overly technical for the students. Instead, we were going to incorporate smaller group talks and workshops based on subject areas of interest. Unfortunately, due to lack of funding for transportation costs, we were unable to pursue this idea.

## Implementation

### *Meeting #1, Note Card Bridges*

October 24, 2007

#### Objective

The objective of this introductory meeting was to introduce ourselves to the student group and give a brief overview of the programs goals and upcoming meetings. A second goal of this meeting was to show that the club would be based on a "hands-on" approach to science and engineering activities.

#### Description

The meeting started out with an attendance of four male students, two of whom had been in the program the previous year. They shared their memories of last year's club, explained which meeting was their favorite, and shared topics they would have liked to see last year if time allowed. The group of four students reviewed our proposed meeting topics and collaborated with Mr. Juneau and us to create a general list of areas they would like to see activities drawn from throughout the year.

Because we were unsure of the length of this introduction and brainstorming session, we chose an activity that could easily be adjusted for time length. The students were presented with various supplies including note cards, construction paper, balloons, rubber bands, straws, paperclips, scissors, and tape and challenged to build a bridge that could support as much weight as possible. The only constraint was that there had to be some span of the structure completely suspended in the air (i.e. not touching the base surface). As the bridge building began, a fifth student came by the room to see what was taking place. After seeing and hearing what we were doing, he decided to stay and participate in the bridge competition. During the bridge building, we circulated around to each of the students, answering any questions they had and encouraging them. After the competition was over and during clean-up, we discussed how the activity related to civil engineering and real bridge building as well as which designs might be capable of being transferred over, and which were successful only for this application.

## Results & Conclusions

At first, the students were hesitant to try designs, but after a little prompting from watching both the presenters and their teacher try unusual designs, the five students seemed less afraid to test their designs and improve upon them. The designs ranged from the extremely simple – paper folded over on itself to form a thin strip and run in parallel across a span – to the extravagant, such as two balloons inflated to relatively the same size and wrapped up in construction paper to form a balloon-supported cylinder. After testing this balloon-cylinder design, the team of two students discovered a fatal flaw in their bridge design – the weight was extremely difficult to balance on their cylinder and kept sliding off. They quickly derived a solution to this problem by creating a parallel cylinder and positioning the weights over the two. This proved to be the winning design overall for the day, supporting more weight than any of the other bridge design. Although there were only five students, none of whom were female, this meeting was successful because it motivated the students to think about science outside the normal classroom setting and got them excited about the meetings in the upcoming months.

## *Meeting #2, Chocolate Asphalt*

October 31, 2007

### Objective

This meeting was planned as an extension of the bridges and civil engineering area from the previous week. The goal was to introduce some of the science and ideas behind asphalt and its components.

### Description

This meeting's attendance consisted of three students from the previous week and a new fourth student who arrived late to see what his friend was doing. The students informed us that there were robotics club meetings after school as well, so a few of the other people they talked to about coming were already busy during the meeting time. To introduce the meeting topic, we reviewed the bridges competition from last week and discussed what other components were necessary for successful traffic ways. Once the topic of pavement came up, the students fairly quickly noted that there were different types of pavement and asphalt. The different applications of pavement were discussed before one student raised the important question of "what makes them different?"

Once this question arose, we revealed the day's activity to be chocolate asphalt and began explaining what each of the materials correlated to in real asphalt. The chocolate asphalt meeting was based on the lesson plans presented by the Society of Women Engineers, shown in Appendix 3. The students then made a few samples of their own asphalt mixtures in various ratios of a melted chocolate mixture, oats, grated coconut, and walnuts. The students then were challenged to smooth out their mixtures, as most pavements need to have a smooth surface, like roads.  While the mixtures were cooling and hardening, the students discussed what their predictions were for the different mixtures' properties, and what the equivalent of that mixture might be in real pavement.  Once the mixtures were cooled, the students examined the samples and tested them for smoothness, resistance to cracking on impact, and flexibility.

### Results & Conclusions

The students quickly recognized the similarities between the real pavement properties and the chocolate pavement supplies they had in front of them.  The students were able to construct a general idea of why each ingredient was important in creating a strong pavement mixture.  Once the pavement diagram was shown, the students identified which of the edible ingredients matched up with each real ingredient.  One student expressed a particular interest in exploring more about civil engineering, and commented that he thought they [civil engineers] just designed buildings before, but bridges were much more interesting.

## *Meeting #3, Film Canister Rockets*

November 7, 2007

### Objective

This meeting used concepts of pressure and potential energy to construct and launch low power rockets. Other topics discussed were basics of aerodynamics and power to weight ratios.

## Description

Attendance this week included four students: three from the previous week and a female newcomer. However, Mr. Juneau informed us that she had attended the club in the previous year. The meeting started off with a brief lesson on the scientific topics relevant to the construction of a self-propelled mass. Then each student was given an empty 35mm film canister and various construction materials (such as paper, cardboard, paper towel rolls, etc.) to build a rocket to their design. They were allowed to have free reign over the design except that the film canister had to be positioned open side out in the aft part of the rocket. As they were constructing, note was given to the students on aspects of weight conservation and the addition of a nosecone and fins for flight stabilization. After they were done with their designs, we then moved outside to a secluded, concrete inlet next to the school building to launch the rockets. An area close to the building was chosen in order to more accurately measure the launch height of each rocket in order to add the notion of competition among the students. One at a time, each student would experiment with adding various amounts of water and Alka-Seltzer to their film canister then closing it off with a cap and letting it stand, build up pressure, and eventually launch. Students were informed that the reaction between the base, sodium bicarbonate, and citric acid in the tablets produced carbon dioxide gas to build up in the canisters.

## Results and Conclusions

Altogether, the students seemed to have a lot of fun with this experiment in that their engineering techniques had a direct impact on the performance of their product. Also interesting to note, the one female participant repeatedly had her rocket fly the highest by a significant margin compared to her male counterparts. She also seemed to be somewhat shy at first but soon loosened up by the end, especially after her rocket proved to be the best design. Finally, students were informed that they would be launching real model rockets after their winter break which showed a considerable spark of interest on the students in the fields of aeronautical engineering. (The date of the real rocket launch turned out to be the last meeting with the students as a club wrap-up.)

## *Meeting #4, Surface Tension Experiments/Penny Floating Experiments*

November 14, 2007

### Objective

This meeting introduced the students to the principles of surface tension of a liquid and the effects it can have on objects placed in it.

### Description

Attendance to this meeting included the three male and one female student from the previous meeting and a new male student, for a total of four male and one female. The meeting began with an informal classroom instruction period on the basic physics behind surface tension and how it's applicable to the experiments that would be performed. The primary experiment that the students performed was to try and "float" various metal objects on the surface of water in a cup. Items included were various coins, pins, and needles. Since the students already knew that the objects don't normally float, they paid special attention to devising ways to balance the objects on the fragile water surface.

After the experiment, we then proceeded to talk about and demonstrate various other applications of surface tension. We filled a clear cylinder with water and had students observe the meniscus formed along the walls of the cylinder and then discussed why that occurred. We then continued to fill the cylinder up to the top and slowly added more water so that a water bulge would form over the top of the cylinder and allowed students to observe it. The next demonstration involved sprinkling different liquids onto a smooth surface, in this case a small mirror, and observing how the droplets formed on the mirror. We used a viscous cooking oil, water, and rubbing alcohol where the oil and water formed dome-like bubbles and the rubbing alcohol spread out in a thin layer until it quickly evaporated.

## Results & Conclusions

Through many trials and much frustration from the students, they finally managed to make a needle stay on the surface without sinking. All the other items sank immediately even with our help as engineers. Again the female had the most success in causing the pins and needles to float while the males tried diligently over and over until each of them too succeeded in floating a needle. Collectively we determined that the long, narrow pin shape was the most ideal because of the decreased mass and large cross-sectional perimeter compared to the coins. The students also took note of the “dimple” formed in the water surface around the pin and compared it to placing a pencil on plastic wrap.

## *Meeting #5, Paper Chromatography, Cornstarch & Water Mixtures, Interest Surveys*

November 28, 2007

### Objective

This week's meeting was intended to be short and simple in nature where a culmination of small, basic experiments would be conducted. A constructed survey was also distributed intended for the students to narrow down any interests in the fields of science and engineering. This survey was self-designed and included the most common technical majors available at most engineering colleges as well as a rating system for each subject area where the students could check off which ones they were interested/uninterested in. A copy of the survey can be found in Appendix 4.

### Description

Attendance for this meeting showed positive retention information, as the four male and one female student returned from the previous meeting. The experiments performed were selected to be "hands-on" and interesting in nature. The first demonstration involved writing on a piece of paper with ink and then dipping the tip of the paper in a cup of water. The intent was that the water would soak up through the paper and separate the various colors that the ink comprised of. Students were encouraged to experiment with all the different variables in this analysis such as: different types of ink, different colors of ink, different paper types, different ink patterns on the paper, and varying the amount of water exposure. This took up nearly half the time of the meeting due to the amount of time needed for water to saturate the various papers, and the student's animated curiosity in finding an optimized ink/paper/water combination.

The next experiment conducted was more of a demonstration and group effort than individual testing. We mixed generic cornstarch and water in a bucket with the expectation of creating a substance that actively stiffens with increased molecular shear velocity. (i.e. the faster you agitate it, the more solid it becomes, and the slower you agitate it, the more it becomes a liquid.)

After cleaning up the classroom of waste materials and water, we then distributed the surveys to the students and gave them all the time they needed to complete them. In which case, they did use the entire rest of the time for the meeting and we could clearly see that each student put a great deal of effort in responding to each question. Refer to Appendix 4 for example survey and results. The survey was based on the areas of major concentration available for pursuit at Worcester Polytechnic Institute. We feel this provided a good breadth of spectrum in engineering without becoming too specific in field. Since the titles of engineering disciplines can sometimes be ambiguous as to what professionals actually do, the parenthetical explanations provided typical ideas of each category. These explanations were developed using each department of study's explanation of its respective field.

## Results & Conclusions

In the paper chromatography experiment, students used their own investigation to try to discover an ideal combination of ink, paper, and water. Their findings were that a softer, more fibrous paper such as construction paper or coffee filter worked the best at soaking up the water throughout the entire piece of paper. The best ink to use was a black colored "sharpie" with a very fine tip with a line drawn parallel to the water above the water surface. The bottom edge of the paper was then submerged slightly below the surface of the water and left there. The water would then permeate up the paper and “drag” the ink line with it, separating the colors out into a spectrum on the paper.

The cornstarch experiment was a failure. Through improper measurement, we added far too much water to the mixture in which case the substance did not harder at all and it remained a liquid. After all around disappointment, we promised to try the experiment again next week and with supplying a much more ample amount of cornstarch to use.

## ***Meeting #6, “Silly Putty” Goop, Cornstarch & Water Re-visited***

December 5, 2007

### Objective

This meeting was designed to introduce the subject of materials science through a hands-on project and allow experimentation to decide the most favorable choice of material combinations. The “failed” cornstarch and water experiment from the previous week was also revisited.

### Description

The meeting started with three male and one female student, all returning students. To gain a base understanding of the audience’s general interest level, the presenters started by questioning what the students thought of chemistry class and lab work. The students responded that the class was “boring” or “hard” and they didn’t care about the subject. After some questioning, one student revealed that he did like the lab experiments, but had trouble staying awake during class. After this resounding, yet not particularly surprising result (Cite stat about HS least favorite class), we started asking about what student’s thought their sneakers, silly putty, and other everyday polymer and polymer based items were made of. The discussion generated a lot of interest as students stumbled upon questions like "could you really make something bounce higher than it originally falls, like the 'flubber' substance?" and possible uses for impact absorbing materials, like highway barriers, suspension systems for bicycles, and many more.

The students were now in a completely opposite mindset about chemistry and lab work. And ready to begin the day's experiment of making "goop" a silly-putty-like polymer, from Borax, glue, and water. The initial Goop mixtures were made according to directions; see Appendix 5, for a control mixture. Because the students each measured the amounts with slightly different accuracies, the mixtures were not exactly the same, but in general they were a bouncy, resilient material that tore upon fast strain rates. We challenged the students to predict what effect each of the additives (salt, cornstarch, baking soda, more glue) provided would have on the Goop properties and create the "Ultimate Goop". They guessed the salt would make it "rougher" and the extra glue would make it stickier, but had no guesses for the cornstarch and baking soda. After numerous generations of Goop, the students declared one to be the bounciest and one the stringiest. They discovered that in general, a little extra glue and cornstarch made the best combination of bouncy and stringy, most similar to actual silly putty.

After the clean up from the Goop experiments, we re-visited the cornstarch and water demonstration that hadn't worked quite so well the previous week. Armed with much more cornstarch this time around, we slowly added water to the cornstarch until the desired consistency was obtained. This mixture actually did exhibit the properties of being solid under high stress but liquid under low stress like we had alluded to in the previous week. We discussed possible applications of viscoelastic substances, such as shock absorption material and new generation body armor. At first the students were resistant to touch the mysterious white material, let alone play with it in hands, but by the end, each of them was experimenting with squeezing the mixture and letting it ooze out of their hand. It appeared that the failed presentation in the previous week worked out alright in the end, because it showed that even though we seem to be "so smart" as one student said, we still make mistakes, and it showed the thinking process of what happens when an experiment does go wrong. We analyzed the situation, sought ways to fix the experiment as it was then with materials available, and seeing that those methods fail, produced the experiment again.

## Results & Conclusions

The students were apprehensive about the "materials science" subject originally brought up, but after discussion of its applications and possible job opportunities, they became excited about the topic and fully participated in the experiments. These two experiments paired together well, as we were able to continue the initial discussion of real applications for these materials to wrap up the meeting. The students left stating they "couldn't wait to show their siblings at home" and smiling. This, coupled with the in depth discussion and ideas initiated towards the end, indicates a highly successful, productive, and informative meeting day for the students. A neighboring teacher at the high school even stopped in to see what was going on during the Goop experiment, and left with her own bag of Goop and instructions on how to make it at home with her children.

## *Meeting #7, Egg Drop*

December 12, 2007

### Objective

The purpose of this meeting was to introduce the design process to students and encourage them to think of creative solutions instead of simply following step by step instructions.

### Description

Since this project was aimed at making the students think independently, we did little initial group discussion of the day's topic. We revealed that we were holding an egg drop competition with the only direction being "individually create a device using the materials allotted that will allow your egg to survive the highest fall and be useable afterwards." The materials included one 4"x4" square of foam per device, the egg carton holder (1 egg indentation per device), paperclips, rubber bands, paper, balloons, drinking straws, tape, scissors, zip-top bags, assorted cardboard boxes and tubes.

The four students (three male, one female; all returning from previous week) each began with the allotted square of foam, but little else surrounding the egg. Then they slowly began perusing the available supplies and developing different strategies for how to prevent the egg from cracking. After approximately 30 minutes, the different contraptions were complete, ranging from a simple but aesthetically pleasing design of a cardboard tube decorated as an elephant, to the more complex design, a cluster of balloons surrounding the egg, as shown in Appendix 6. Even Jeff decided to participate and construct an egg drop contraption. With the five final products completed, we ventured outside for the testing.

The initial drop was from the top of a cut-away hill overlooking a pavement patch, approximately fifteen feet below. The test consisted of dropping the egg-protection contraption a height of approximately fifteen feet onto a pavement patch, were it would hopefully arrive intact. The first casualty was Jeff's contraption, as the egg rolled out the side and fell next to the balloon clusters instead of safely within its protection. The elephant-shaped contraption also failed this test, landing with a decidedly loud crack; the issue this time being not egg movement, but lack of padding. The other models passed and progressed to being thrown at the ground from the same fifteen foot height, causing one other model to fail. With two contraptions remaining, we sought a higher dropping site, the second story window. From here the box contraption fit easily out the window and landed hard on the grass, cracking the egg. The female student's super-cluster of balloons with egg firmly held inside barely fit through the window, and gently bounced on the ground, being blown away in the wind. This was declared the winner and we went back inside to evaluate the activity.

Looking back on the project, students identified why and how the models failed and how they could be improved upon. Suggestions included better egg restraints, more impact absorption, protect from impact on all sides, not just one since it may tumble and land not on desired side. Specific ideas included using more foam, making sure parachute opened, and one student even brought the idea of using the previous week's goop to absorb some of the impact of landing.

We led a discussion on the real uses of this sort of idea, scaling up the egg drop into something used in practical applications, students mentioned space probes and surface rovers; and food and supply drops from airplanes for soldiers and refugees, all of which are deployed from a height and need to arrive safely and intact at a specific destination. We also asked each student to quickly review how they went about deciding what to build, and introduced the design process that way. They were given a problem, generally brainstormed possible ideas, started creating what they believed the most feasible solution to be, and made adjustments to the plan as they went along and either found new materials, had new ideas, or adjusted to the time constraints.

## Results & Conclusions

At first the students were “stuck” on the idea of using the egg carton square, presumably since that is what they are used to seeing eggs in. Slowly the different ideas emerged and branched out from one another to cover a wide spectrum of approaches and materials used. Straws, seen as frivolous to one, were a main component in another. The students continually asked if they could do something, to which we would reply by simply referring them to the rule statement. Eventually the students stopped asking if something was allowed and simply built their contraptions. Even the students who had been to the previous year’s egg drop used different contraptions than they had done since the supplies and rules had changed slightly. Overall, the meeting served as a good quick, general, and fun introduction to the design process. The eggs and foam were the only new supplies needed for this experiment; the rest were residual supplies from previous meetings. The clean up was the minimal since the drop tests were outside.

By this point in the project, it was clear that the engineering club had developed a consistent core group of participants as evidenced by attendance over the past meetings, but was struggling to expand the overall number of participants.

## *Meeting #8, Robot Hands*

January 30, 2008

### Objective

This meeting aimed to broaden the scope of the club projects, predominantly mechanical engineering or mechanical related, by introducing a biology-related topic, how tendons and muscles work, specifically, how they work in the hand and fingers.

### Description

This project started with a brief discussion on how muscles work together to produce movement within the body. In the most basic sense, muscle work in opposing pairs contracting and relaxing. One set is responsible for extension, and the opposite is responsible for flexion motion. As an example, the students felt their arms while flexing and relaxing.

The "robot hands" were constructed from paperboard and had jointed segments resembling a finger, refer to Appendix 7 for detailed assembly instructions. One string, or set of strings, ran along the inside of the boxes, and one ran along the outer boxes. Pulling the inner string simulated muscle contraction and caused the finger to bend forward, as well as forcing the opposing string running on the outside to go into relaxation. Pulling on the outside string caused the finger to return to the fully extended position, as well as forcing the inner string to go into relaxation. The students were able to see that if they pulled on both strings at the same time, nothing happened. Similarly, if they left both strings lax, nothing happened. They were able to see the working relationship between muscle pairings.

## Results & Conclusions

One student brought up that he had heard of tendons being cut and replaced in other injured parts of the body, which transitioned into a discussion of growing artificial muscles, bone grafts, and implant devices. The discussion stemming from the muscles and tendons simulation seemed to particularly interest one female student in the group who had expressed an interest in the matter before, but now was looking into which colleges offered rigorous courses in biology and biology related fields.

The meeting attendance had the core group of three males, one female, with an additional female freshman attending, for a total of five participants. The new female, unaware of the club's existence, said she was there to make up a test, but ended up staying and participating in the activity. The fact that she was unaware of the group's existence leads to the conclusion that perhaps new advertising strategies should be investigated for future years, such as a large kick-off type event, then recurring meeting afterwards. The project is fairly simple, produces little clean up, and is low cost as most of the materials are reused from previous meetings.

Unfortunately, the club did not meet for the next three weeks due to two cases inclement weather and the third week was February vacation for the Worcester Public Schools.

### *Meeting #9 and #10, Building Model Rockets, and Launching of Rockets*

February 27, 2008 and March 5, 2008

## Objective

This activity and experiment was spanned out over the course or two meetings. The first meeting was solely utilized to design and construct individual rockets from mixing and matching pieces of different rocket kits. The second meeting was used to go outside to the sports field and launch each person's rocket as many times until our engine supply was depleted.

## Description

During the first meeting, we started off by talking about the principles behind rocketry and aerodynamics such as thrust/weight ratios, use of fins and stabilizers, and a brief history of rocket development. We then proceeded to allow the students to construct their rockets either by following instructions supplied by the kits or by using their own originality and creativity. Of course, originality would be curbed if a student's design was clearly dangerous to fly, but all students kept to fairly typical rocket designs and no instructor intervention was necessary. Kits used were identical "A-engine" sized rockets bought in bulk from the Estes model rocket company. The instructors, Amanda and Jeff, also proceeded to construct their own rocket designs as well. Due to the time required for glue to dry and the overall delicacy of rocket construction, the entire meeting period was used for such construction.

The second meeting started off by eating Dominoes pizza while the students adding any final touches to their rockets as necessary. After everyone was set to go outside, we then gave an operational and safety briefing in the form of a PowerPoint presentation on a laptop computer. Topics included: proper handling and components of an A8-3 model rocket engine, procedure of launching a rocket safely, situational awareness, and what to do in case of malfunction or emergency. Everyone then proceeded outside to the nearby recreational field and set up a launch site in accordance with the current wind patterns that day. Each student launched their rockets at least twice until all engines were consumed.

## Results & Conclusions

Overall, each of the five student's rocket flew successfully and well except for one launch where the student's rocket became stuck on the launch rod and did not fly even though the engine ignited. Because proper safety procedures were followed, there was no danger presented towards any of the personnel on the site. Of all the rockets launched, the worst designs were surprisingly those of the instructors in which both of their rockets flew up in an erratic spiraling formation. Yet, all of the students managed to apply their knowledge of rocketry to cause each of their rockets to fly straight and correctly.

Furthermore, one of the students was concurrently working on a video for a welcome presentation for incoming freshmen to the high school, and he needed some candid footage of various clubs and activities at the school. Aside from recording some of the launches, he also sat down with the instructors in the classroom afterwards we gave a brief, informal interview about the club and the reasoning behind it.

# Conclusions

Overall, the entire evolution was a complete success. The planning, coordinating, execution, and outcome all ensured the accomplishment of continuing the Future Engineers Club at Burncoat High School. The most significant aspect of success was having a suitable number of high school students interested in the club and consistently attending the meetings. As previously noted, there was a consistent group of about five students, one of which was female, who showed great enthusiasm in the fields of science and engineering. Midway through the meeting span, we distributed a simple survey (Appendix 4) to help the students self-evaluate where they felt the most interest in various sciences. Results are also displayed in Appendix 4 with the highest result in Fire Protection Engineering and the lowest overall interest in Mathematical Sciences. The low interest topic is understandable in that many high school students may not be fond of doing strict math for a career, but it is interesting to note that Fire Protection Engineering received the highest interest over other common disciplines such as mechanical engineering and robotics. At any rate, the goal of sparking the interest of science and engineering in a predominantly arts and literature based high school was met completely and exceeded so much as a few of the upper class students mentioned an interest in checking out various engineering based colleges in the region.

## Recommendations

Although this interactive qualifying project was a complete success, there were a number of difficulties that arose and needed to be assessed. The most significant issue was communication between us and the advisors; particularly Mr. Juneau. Primary means of contact was through email and Mr. Juneau specifically said that he doesn't regularly check his email daily. However, Professor Clark checked his email frequently and was regularly responsive, but there was still a lag in this form of communication and if plans had changed on any given day then it was difficult to coordinate information quickly. For the future, it may be wise to still use email as the primary means of communication but then to also exchange cell phone numbers in case of urgency. This way, in the very least, one could leave a voicemail of send a text message to the others of concern.

Along the lines of time loss, it is imperative to start the project as early as possible in A-term so as to coincide with the high school's academic calendar. A minor issue this year was having multiple school breaks in the winter and spring months such as Christmas/New Years, high school winter break, high school spring break, and college spring break to name a few. This resulted in long tracts of not having meetings with the students and could result in loss of interest. This could be combated in the future by scheduling the meetings earlier on in the school year so that the project group can wrap in up in the beginning of C-term.

# Resources

Byko, M. (2001). Demand for Engineers May Exceed Supply of College Graduates. *Journal of Minerals* , 43.

DeLuca, E., & Fradella, C. (2007). *Future Scientists and Engineers Club.* Interactive Qualifying Project. Worcester: Worcester Polytechnic Institute.

Dorchik, B., & Duncan, M. (2006). *A Future Scientists and Engineers Club for Doherty High School: a Pilot Project.* Worcester: Worcester Polytechnic Institute.

Landers, K. (2007, December 7). Engineering Dominated by Male Students. *The Brown and White* .

Macdonell-Laeser, M., & Moskal, B. M. (2001). The Engineering Process: Examining Male and Female Contributions. *ASEE/IEEE Frontiers in Education Conference.* Reno, NV.

Marklein, M. B. (2005, October 19). College Gender Gap Widens: 57% are Women. *USA Today* .

Massachusetts Department of Elementary & Secondary Education. (n.d.). *Burncoat Senior High - Enrollment/Indicators*. Retrieved April 19, 2008, from http://profiles.doe.mass.edu/home.asp?orgcode=03480503&view=enr

Worcester Public Schools. (2006). *2006-2007 Report Card - Burncoat Senior High.* Retrieved April 19, 2008, from http://www.wpsweb.com/administration/federal/docs/reportcards/burncoat_high.pdf

# Appendices

## *Appendix 1, Burncoat High School Data*

### Burncoat Senior High - Enrollment/Indicators

**Enrollment by Grade (2007-08)**

| | pk | k | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | SP | CT | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| District | 725 | 1,883 | 1,811 | 1,856 | 1,665 | 1,660 | 1,625 | 1,598 | 1,571 | 1,520 | 2,021 | 1,690 | 1,716 | 1,531 | 4 | - | 22,876 |
| School | - | - | - | - | - | - | - | - | - | - | 385 | 291 | 304 | 303 | 0 | - | 1,283 |

**Enrollment by Race/Ethnicity (2007-08)**

| Race | % of School | % of District | % of State |
|---|---|---|---|
| African American | 16.8 | 12.9 | 8.1 |
| Asian | 3.8 | 7.8 | 4.9 |
| Hispanic | 32.4 | 35.7 | 13.9 |
| Native American | 0.6 | 0.4 | 0.3 |
| White | 45.7 | 40.7 | 70.8 |
| Native Hawaiian, Pacific Islander | 0.0 | 0.0 | 0.1 |
| Multi-Race, Non-Hispanic | 0.6 | 2.4 | 1.9 |

**Selected Populations (2007-08)**

| Title | % of School | % of District | % of State |
|---|---|---|---|
| First Language not English | 36.1 | 39.7 | 15.1 |
| Limited English Proficient | 11.9 | 20.6 | 5.8 |
| Low-income | 54.6 | 65.2 | 29.5 |
| Special Education | 20.9 | 19.9 | 16.9 |

**Technology (2005-06)**

| | School | District | State |
|---|---|---|---|
| Students per "modern" Computer | 5.1 | 3.3 | 3.8 |
| Classrooms on the Internet (%) | 100.0 | 100.0 | 97.9 |

**Enrollment by Gender (2007-08)**

| | School | District | State |
|---|---|---|---|
| Male | 634 | 11,815 | 494,970 |
| Female | 649 | 11,061 | 467,796 |
| Total | 1,283 | 22,876 | 962,766 |

**Plans of High School Graduates (2006-07)**

| Plan | % of School | % of District | % of State |
|---|---|---|---|
| 4-Year Private College | 24 | 18 | 31 |
| 4-Year Public College | 20 | 22 | 27 |
| 2-Year Private College | 1 | 2 | 2 |
| 2-Year Public College | 30 | 40 | 20 |
| Other Post-Secondary | 6 | 3 | 3 |
| Work | 9 | 10 | 10 |
| Military | 2 | 2 | 1 |
| Other | 0 | 1 | 1 |
| Unknown | 8 | 4 | 6 |

**Indicators (2006-07)**

| | School | District | State |
|---|---|---|---|
| Grade 9-12 Dropout Rate | 7.3 | 6.0 | 3.8 |
| Attendance Rate | 90.3 | 94.0 | 94.6 |
| Average # of days absent | 15.9 | 10.1 | 9.3 |
| In-School Suspension Rate | 24.3 | 10.2 | 3.2 |
| Out-of-School Suspension Rate | 22.9 | 13.7 | 5.8 |
| Retention Rate (2005-06) | 11.8 | 4.2 | 2.5 |
| Graduation Rate | 63.5 | 69.8 | 80.9 |

**Teacher Data (2007-08)**

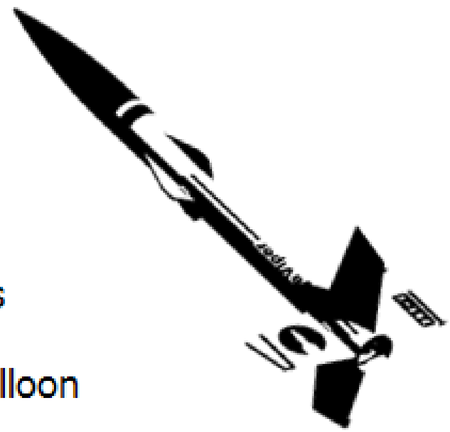
| | School | District | State |
|---|---|---|---|
| Total # of Teachers | 85 | 1,602 | - |
| % of Teachers Licensed in Teaching Assignment | 94.1 | 97.0 | - |
| Total # of Teachers in Core Academic Areas | 325 | 6,319 | - |
| % of Core Academic Teachers Identified as Highly Qualified | 99.1 | 97.8 | - |
| Student/Teacher Ratio | 15.1 to 1 | 14.3 to 1 | - to 1 |

Source: Massachusetts Department of Elementary and Secondary Education.

## *Appendix 2, School Flyers*

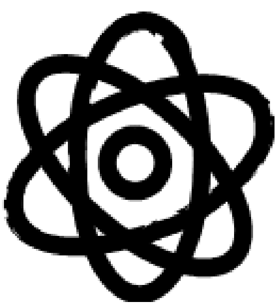
The first flyer was posted on school bulletin boards and distributed in science classes. The second flyer was distributed to students who demonstrated interest in the program. It also explains a little bit of the background as to why the club was started.

# Science Club



Ever want to….

Make Edible Asphalt (it's really good)
Build and Launch a Rocket
Find DNA in Everyday Things
Design a Bridge
Launch a Hot Air Balloon
Visit WPI
Talk to college students about science or college in general?



You can do all these and more at Burncoat High Science club meetings!

Come along to our first meeting to find out what it's all about, or stop by on any meeting day to join in.

See Mr. Juneau in room D16 for more information

Amanda and Jeff
(WPI students sponsoring the club)

# The Future Scientist and Engineers Club
# At Burncoat High School

**Purpose** The purpose of the club is to bring an appreciation for the sciences and engineering fields to the Worcester Public High Schools.

**Meetings** Meetings for Burncoat High will be held in room D16 directly after school on Wednesdays, beginning mid October. Meetings will be run by college students from WPI[1] and supervised my Mr. Juneau of Burncoat High. A few examples of possible meetings may include (but are not limited to):

| | |
|---|---|
| Chocolate Asphalt: | Students will learn the composition and structure of asphalt. They will then make it themselves using chocolate. |
| Building Design: | Students will design a building using Lego's or similar material. Restrictions and constraints lead them to design the best building possible. |
| Engineering overview: | WPI's admissions office will give an interesting and general view on different types of engineering. |
| Rocket Launch: | Students will learn the basics of aerodynamics to design and construct a model rocket from scratch, then launch them outside. |
| Bridge design: | Students will learn concepts of structural analysis in order to design and build a bridge popsicle sticks or similar material. Prizes go to those who build the strongest and longest. |

**Why Join** The Future Scientist and Engineers Club is set up to help students learn about the different sciences and engineering fields. Knowledge of these fields could help in making choices for college or choosing your future.

The college students organizing the group are from WPI. They have developed a strong interest in bringing groups to five local high schools and leading these groups during meetings. With help from the high school students, we can make these clubs a possibility to continue in local Worcester high schools.

**See Mr. Juneau in room D16 to sign up!**

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[1] All WPI students involved with this project have had CORI (Criminal Offender Record Information) background checks and have no prior criminal records.

## *Appendix 3, Chocolate Asphalt Information*

The materials, directions, and background information for chocolate asphalt cookies are presented according to lesson plans provided by the Society of Women Engineers, available at <http://www.swe.org/iac/lp/asphalt_02.html>.  Further information is available from the Society of Women Engineers Headquarters: 230 E Ohio St Suite 400, Chicago, IL 606011-3265.

### Materials (Cookie Ingredients for 8 Students):

- 1/3 Cup Cocoa Powder or Carob
- 1/2 Cup Milk
- 1/4 Pound Butter (1 Stick = 1/4 Pound)
- 2 Cups Sugar
- 8 Tablespoons Chopped Walnuts In A Plastic Bag
- 8 Tablespoons Flaked Or Shredded Coconut In A Plastic Bag
- 1 Cup Old Fashion Oats In A Plastic Bag
- 1 Cup Quick Cooking Oats In A Plastic Bag

**Supplies:**

- Medium (2 Quart) Pot
- Crock Pot Or Other Heat Source
- Extension Cord
- Large Wooden Spoon
- Ladle
- 1/4 Measuring Cup
- 1/8 Measuring Cup
- Tablespoon Measure
- Water and Paper Towels for Clean Up

**For Each Student:**

- Steep Sided Bowls or Large Paper Cup
- Sturdy Spoons
- Wax Paper Cut Into 12" squares
- 16 oz. Sealed Can or Rolling Pin

### Directions

1 Prepare the "chocolate asphalt" in advance. In a medium size pot combine the cocoa powder, milk, butter and sugar. Heat, stirring frequently until the mixture boils for 2 minutes. Pour into the crock pot set at highest temperature. Yields 2 cups (8 1/4 cup portions). Double or triple as needed.

2 Review the information in the background section. Check out the photo gallery for this lesson! Consider printing out these pictures for a class display.

3 Using the measuring cup and tablespoon, measure the following ingredients and pour them into your mixing bowl or paper cup:
- 1/8 cup old fashion oats
- 1/8 cup quick oats
- 1 tablespoon walnuts
- 1 tablespoon coconut

4 Compare the edible construction materials to the pictures of the actual asphalt construction

materials. List the similarities and differences between the edible and real construction materials. Consider weight, roughness, thickness, overall size, porosity.

Real Asphalt Construction Materials

5 Look at the liquid form of the chocolate asphalt in the crock pot. When asphalt binder is heated to 300° F, it is also a liquid. Using the ladle, spoon and measure 1/4 cup chocolate asphalt into the materials mixture.

Chocolate Asphalt Cookie

6 Look at the picture of the drum mixer from the asphalt plant. It tumbles all of the construction materials until they are well coated with the asphalt binder. The tumbler works like a clothes dryer. Mixing the ingredients in the bowls is a similar process.

Drum Mixer

Stir until all of the materials are well coated. Notice - the mixture cools while you stir it, becomes stiffer and starts to stick together. Asphalt behaves in the same manner.

7 When the materials are thoroughly mixed, pour the mixture into a mound on a square of wax paper. Cover with a second piece of wax paper.

8 In the field, the pavement is spread with a paver and then rolled into a thin mat with a roller. The roller is very heavy and pushes all of the air out of the pavement. This helps make the asphalt very strong. Use a can or rolling pin to roll your cookie mixture 1/4"-1/3" thick. Can you still identify the different materials in the cookies?

9 Place your hand over the top of the cookie. Do you feel the heat? When asphalt pavement is first rolled out it is still very hot. Just like the asphalt, the cookies will harden as they cool. (Do you think that the cookies would be as strong if you use less edible materials? More edible materials?) When the cookies have cooled and hardened (20-30 minutes), you can peel off the wax paper and eat. Congratulations!

## Background Information:

A variety of materials, machinery and processes are used in the preparation of road paving materials. While you make the chocolate asphalt cookies you will compare the processes and properties of the edible cookie construction materials with actual construction materials and processes.

Check out the photo gallery for this lesson! There are pictures of an asphalt plant, drum mixer, construction materials, asphalt samples and laboratory mixing and testing equipment. Click on any picture in the gallery for a larger version. Consider printing and using these pictures for a class display.

Paving materials, like asphalt, are manufacturing in a plant. An asphalt plant has many parts. There are areas to store and weigh the construction materials, machinery to make the asphalt and a laboratory to test samples for strength and durability.

Asphalt is a combination of "aggregate" and "binder". Aggregates are textured rocks and sand-like materials. Aggregates come in different sizes and textures: coarse, fine or very fine. Most aggregates come from nature: crushed rock or gravel for coarse aggregates; natural sand or finely crushed rocks for fine aggregates. Very fine aggregates are called "fillers". Common fillers are limestone dust or cement.

Aggregates - Notice The Different Size And Textures Of Rocks

The rocks and other aggregates are stored in stockpiles (large piles) at the asphalt plant. The stockpiles are located near conveyors. The conveyors look like little roller coasters or monorail systems. There are small bins in the conveyor and the rocks or aggregate are scooped into the bins. The conveyor transports the bins around the asphalt plant where the materials are needed.


Stockpile and Conveyor System

The binder is the material that holds (binds) the mixture together. In the past tar was used. Today a substance called bitumen is used as the binder. When the binder is heated to $300^{o}$F, it turns into a liquid. When it cools it turns into a hard solid mass. Rocks or aggregate are added to the binder to make the asphalt stronger.

Engineers select and calculate the correct quantities of each rock size needed to produce a strong asphalt pavement. Calculated percentages of the different sizes of rocks are combined to determine the appropriate blend of rock materials. The mixture of rocks and asphalt binder are then compacted and put through a series of tests which smash, stretch, and freeze the pavement to determine the best blend of rocks to use in a certain climate.


Different measuring techniques are used in the field than in the laboratory. In the field engineers use huge quantities of each rock size and weigh them on scales as large as a garage. In the laboratory, much smaller quantities of each material are needed and ordinary measuring utensils are used.

The drum mixer at the asphalt plant tumbles all of the ingredients until they are well coated with the asphalt binder. The tumbler works like a clothes dryer. Mixing the ingredients in the bowls is a similar process. As the cookie mixture cools while it is being stirred, it becomes stiffer and starts to stick together. Asphalt behaves in the same manner.

In the field, the pavement is spread with the paver and then rolled into a thin mat with a roller. The roller is very heavy and smashes all of the air out of the pavement which helps to make the asphalt very strong. You can still see the different materials in the asphalt. Immediately after pavement is rolled out it is still very hot.

## *Appendix 4, Student Interest Survey*

Please rate the following areas from 1 (not interested) to 5 (very interested)

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Aerospace Engineering (design of airplanes, space systems) | | | | | |
| Biology / Biotechnology (discover how body systems work) | | | | | |
| Biomedical Engineering (develop devices to work with the body) | | | | | |
| Chemical Engineering (make new substances based on needs) | | | | | |
| Chemistry / Biochemistry (discover new properties of matter) | | | | | |
| Civil & Environmental Engineering (design safe structures that fit the surroundings) | | | | | |
| Computer Science (make computer programs people will use) | | | | | |
| Electrical Engineering (develop wireless communications, generate power) | | | | | |
| Fire Protection Engineering (design systems to protect lives & property from fire) | | | | | |
| Mathematical Sciences (use math for prediction and analysis) | | | | | |
| Mechanical Engineering (design & construct devices from blenders to reactors) | | | | | |
| Physics (study how forces interact, from subatomic particles to galaxies) | | | | | |
| Robotics (design machines to perform tasks) | | | | | |

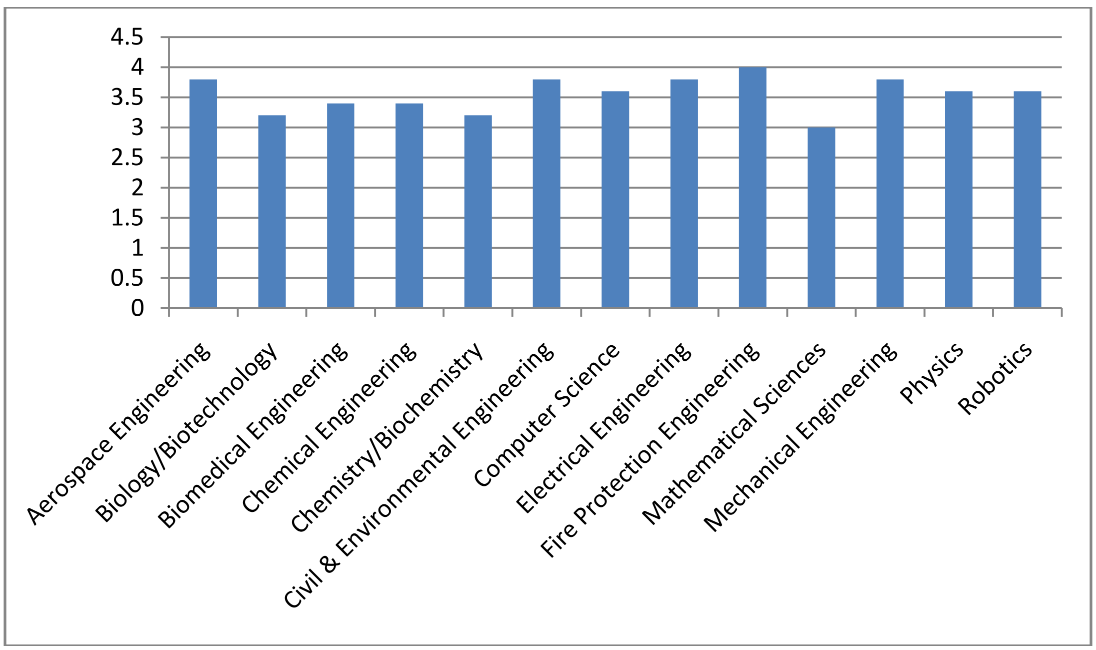
So far, what was your favorite activity & why?

What was your least favorite & why?

Name:

## Survey Results:

| Subject Area | Number of Responses | Mean Ranking | Lowest Ranking | Highest Ranking |
|---|---|---|---|---|
| Aerospace Engineering | 5 | 3.8 | 2 | 5 |
| Biology/Biotechnology | 5 | 3.2 | 1 | 5 |
| Biomedical Engineering | 5 | 3.4 | 1 | 5 |
| Chemical Engineering | 5 | 3.4 | 2 | 5 |
| Chemistry/Biochemistry | 5 | 3.2 | 1 | 4 |
| Civil & Environmental Engineering | 5 | 3.8 | 2 | 5 |
| Computer Science | 5 | 3.6 | 2 | 5 |
| Electrical Engineering | 5 | 3.8 | 3 | 5 |
| Fire Protection Engineering | 5 | 4.0 | 3 | 5 |
| Mathematical Sciences | 5 | 3.0 | 2 | 4 |
| Mechanical Engineering | 5 | 3.8 | 2 | 5 |
| Physics | 5 | 3.6 | 2 | 5 |
| Robotics | 5 | 3.6 | 3 | 5 |



## *Appendix 5, "Silly Putty" Goop*

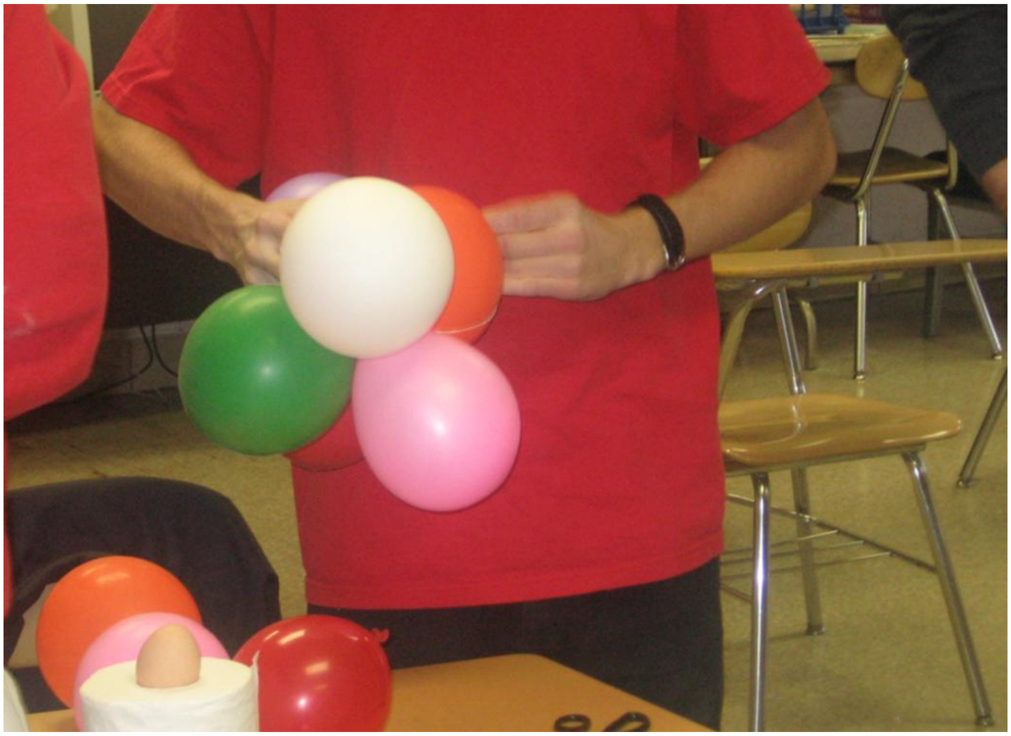
### Materials & Supplies

- Borax (laundry enhancer)
- White glue
- Water
- Salt
- Cornstarch
- Baking Soda
- 2 separate mixing cups/bowls per batch

### Directions

1. In one cup, create a dilute Borax solution using the ratio ½ teaspoon Borax : 4 Tablespoons water.
2. In the second cup, thoroughly mix 4 Tablespoons each of white glue and water.
3. Pour the Borax mixture into the glue mixture and stir. Material will begin to thicken and become more like the commercial silly putty.
4. Remove the clumped mixture from excess water and knead it slightly and the mixture will come together.

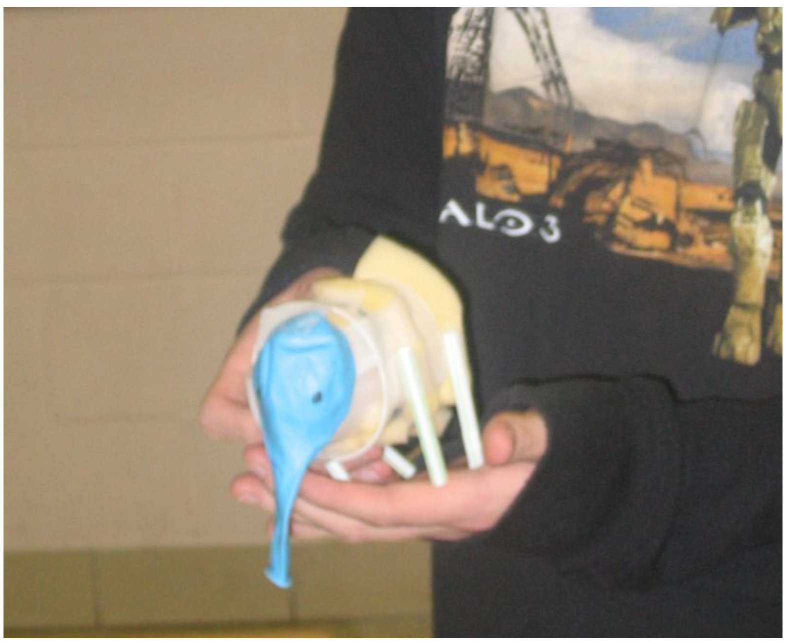
## *Appendix 6, Photos of Egg Drop Entries*



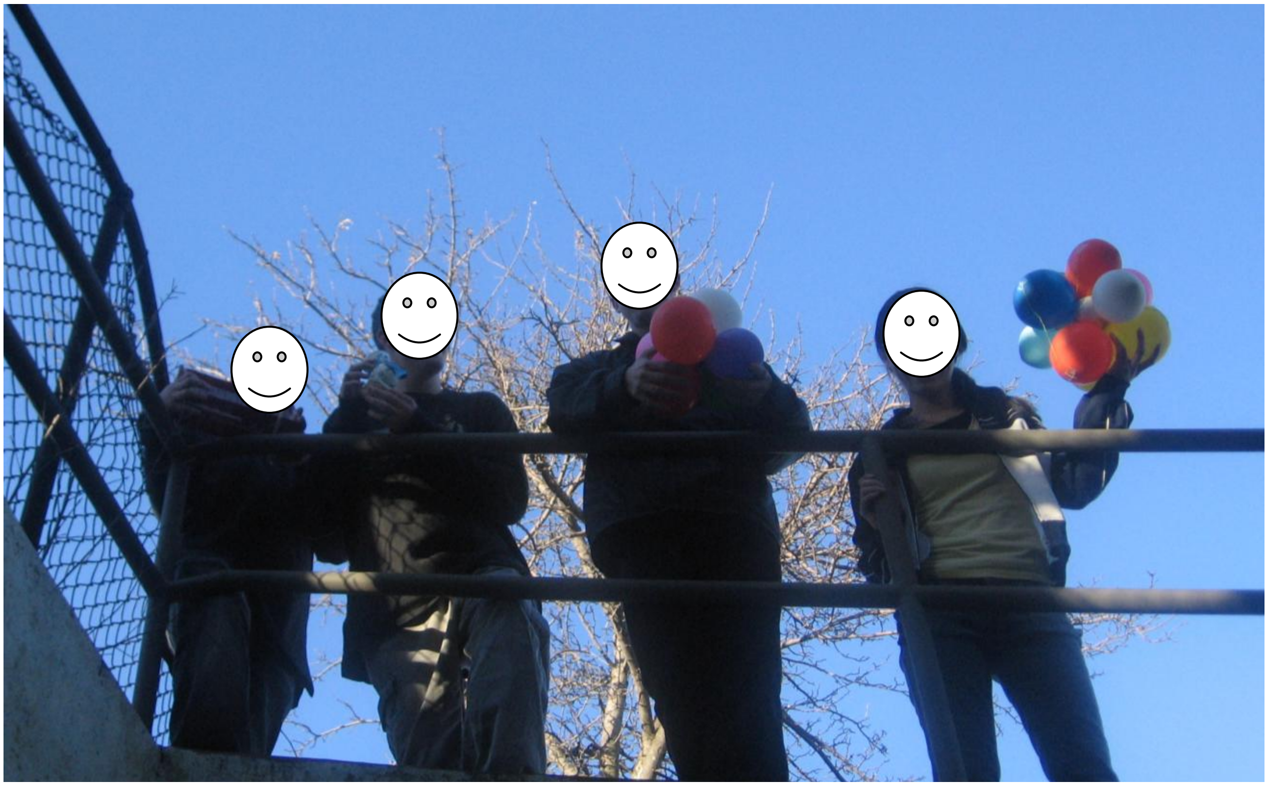
Jeff (presenter) making his balloon cluster.

The cardboard box contains a paper cup packed with foam and paper and the egg, held in place by balloon parts, straws, and tape.

Another design in progress, a Ziploc bag with assorted cushioning, surrounded by balloons.



One of the more artistic entries, the cardboard tube elephant-shaped egg protector.



The egg drop contestants ready their devices and themselves for the first round.

The winning design, large cluster of balloons.


The egg drop champion of Burncoat High 2007-2008 Engineering Club proudly poses with her egg.

## *Appendix 7, Robot Hands*

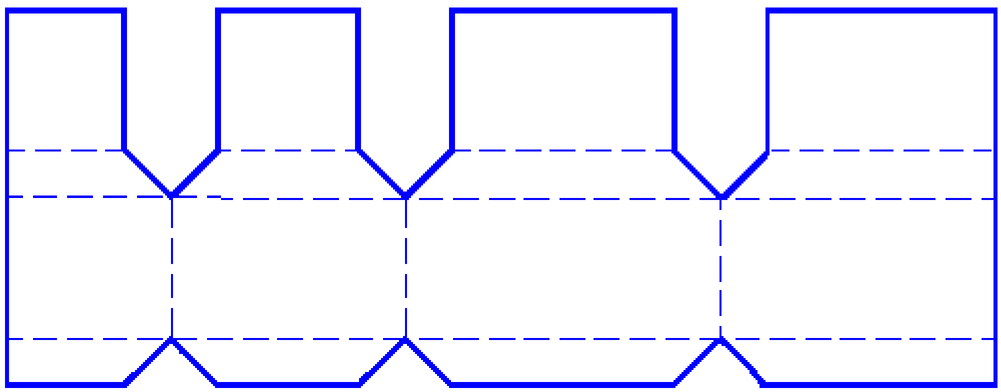
The construction of the "robot hands" is presented as described by Slater Harrison at <http://www.sciencetoymaker.org/robotFinger/assembl.html>

### Materials

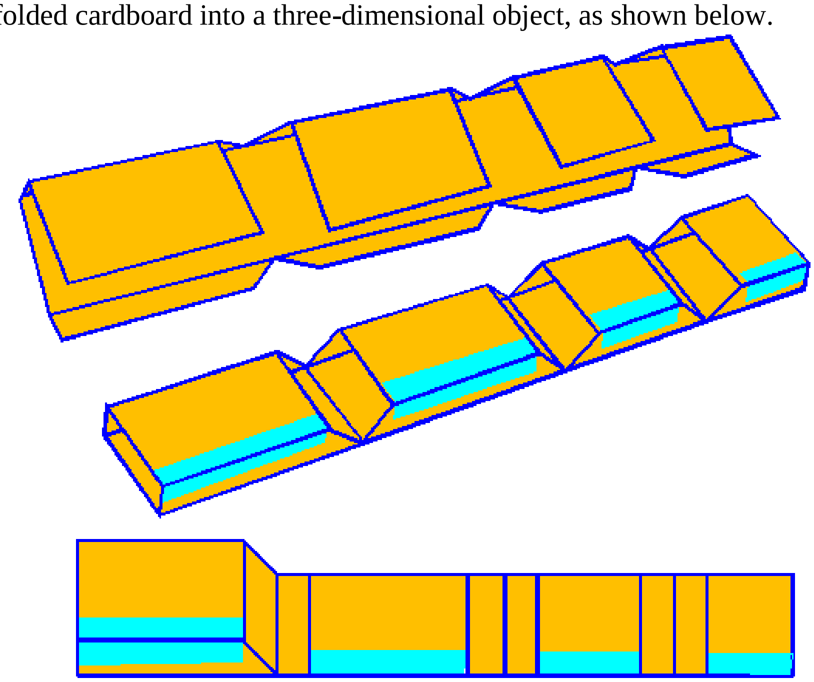
- String
- Thin cardboard (cereal boxes or similar)
- Scissors
- Tape

### Directions

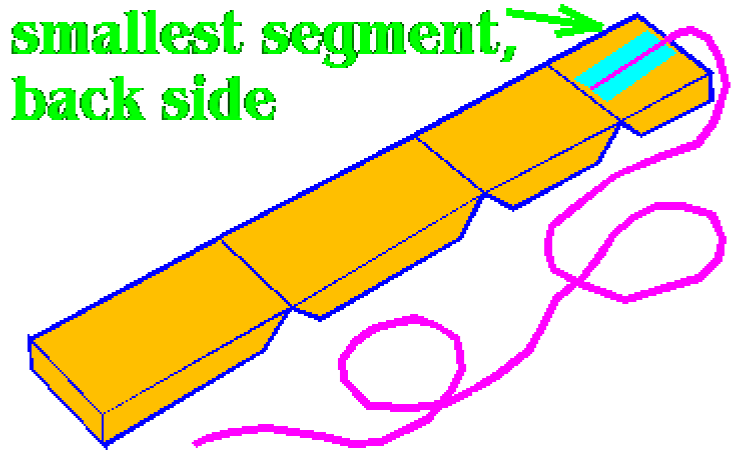
1. Cut out the cardboard using the pattern below



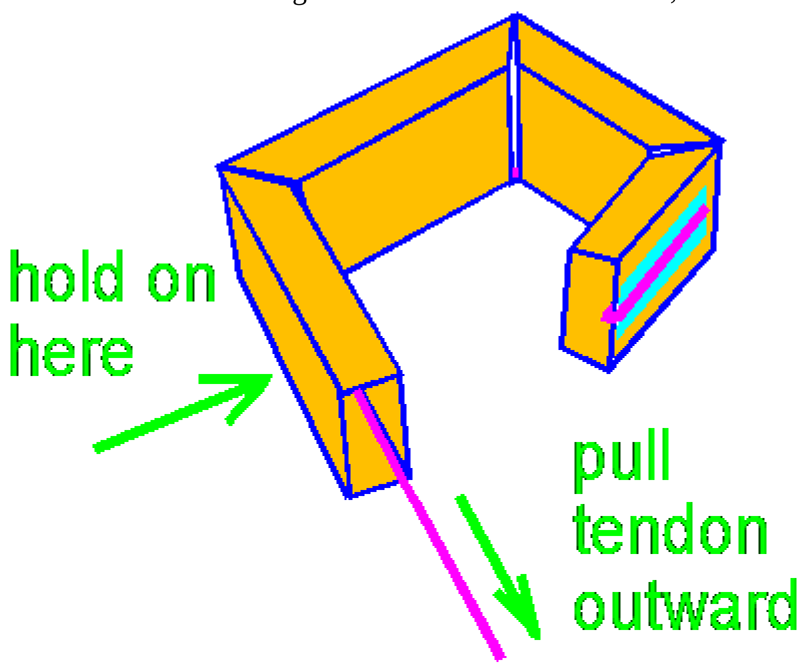
2. Fold on the dotted lines, using the sharp edge of a table or a ruler facilitates straight folds. When all the folds are in place, remove the paper pattern.
3. Tape the folded cardboard into a three-dimensional object, as shown below.



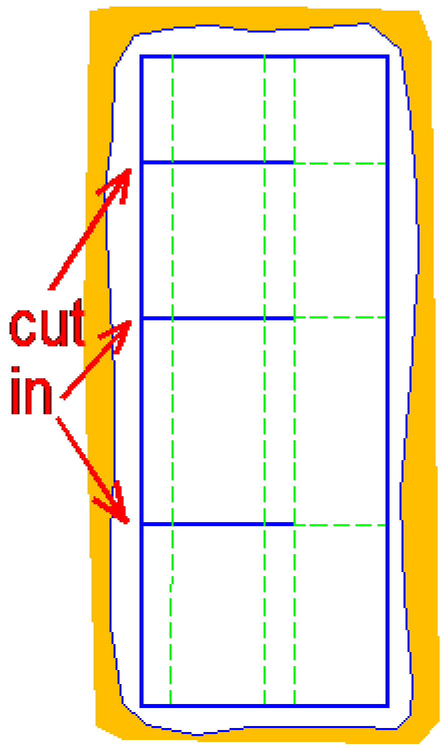
4. Tape the string to the back (flat) side of the smallest segment, as shown. Thread the string through each open trapezoidal box so that the string ends going out the center of the largest segment.



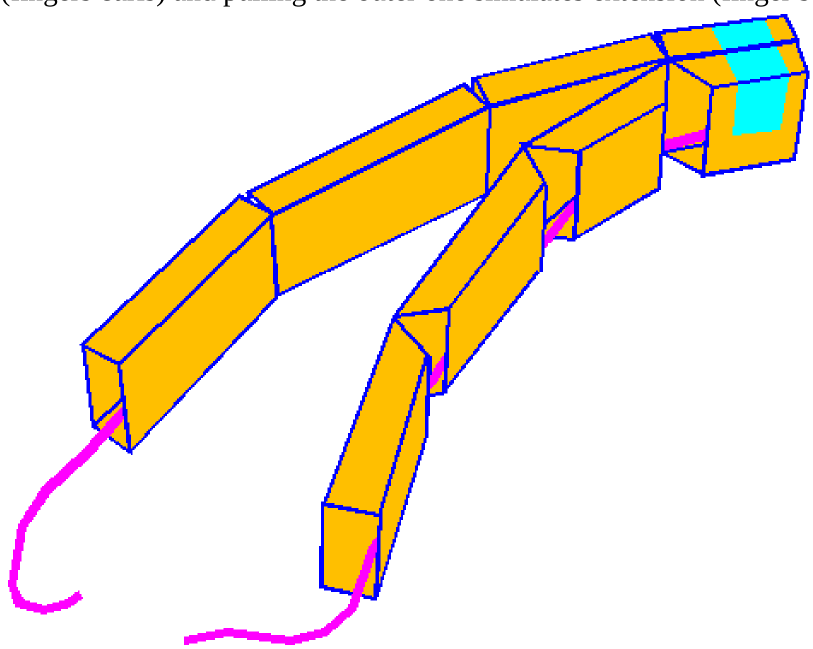

This creates the basic finger that can demonstrate flexion, as shown below.

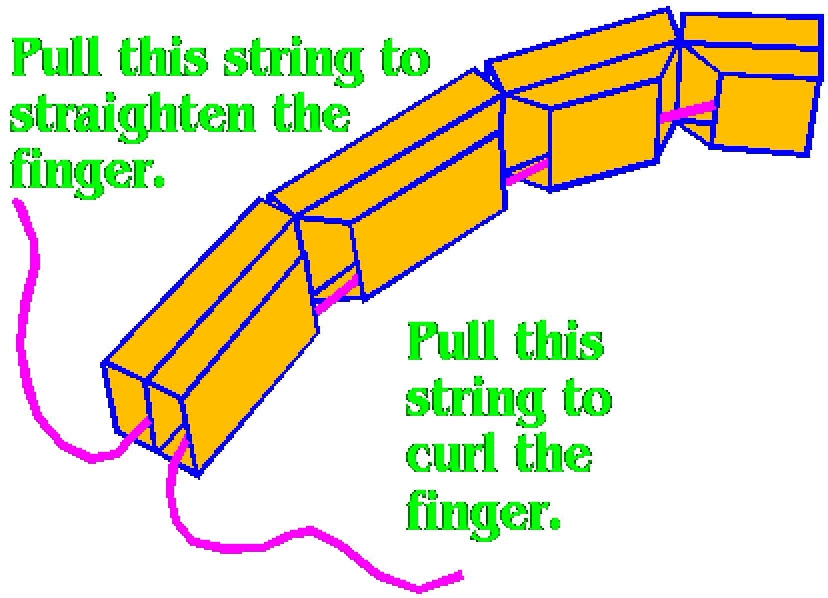



5. To add an opposing tendon and make the finger capable of extension, cut from cardboard a piece matching this pattern. Fold on dotted lines and remove paper pattern. Tape the folded segments together as before to form segments of the finger.




6. Again, tape a string to the back of the smallest segment and feed it through to the largest. Then tape this addition to the simple finger from before. Pulling the inner string simulates flexion (fingers curls) and pulling the outer one simulates extension (finger straightens).






7. To continue and make an entire hand, make five fingers total and fix them to a solid cardboard base, as shown.