Tech Prep Camp: Introducing High School Students to Engineering Technology through Model Rocketry

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Abstract

Penn State Erie, The Behrend College participates in Pennsylvania’s Tech Prep Program. Articulation agreements between Penn State Erie and participating local high schools are designed to recruit students into two year programs. Students meeting the specified requirements upon graduation from high school are automatically granted admission to Penn State Erie.

Penn State Erie hosted a week long residence camp exposing high school Tech Prep students to hands on experiences. Activities for the camp focused on manufacturing in the Electrical Engineering Technology, Mechanical Engineering Technology and Plastics Engineering Technology programs, through the study of model rocketry.

The first day of camp, the students were exposed to the assembly line process by building an electronic ignition system for model rockets. They also assembled the Alpha rockets that would be launched in the afternoon.

The second and third day, students rotated through lectures and laboratories on the following topics - basic DC circuit fundamentals, assembly drawings of the Alpha rocket and a rocket holder with Computer-Aided-Drafting (CAD) and using a solid modeling program called SolidWorks®. Demonstrations included cutting the rocket holder on a CNC Router to be used as a vacuum forming mold in the plastics lab.

The fourth morning, the students chose between a laboratory in which they would construct and test a digital voltmeter, or a laboratory to learn about operations and experimentation in a wind tunnel. Calculations of drag forces were discussed and tests of the student's competition rocket were performed to determine the actual drag coefficients.

To keep students interested, a rocket competition was held which allowed them to apply the principles they had learned during the week. During each lunch period, speakers discussed career opportunities, high school class requirements, financial aid and college success tips. The last day, students visited local industry and were given the opportunity to job shadow.
1.0 Background

The Tech Prep program is a federal program designed for high school students interested in attaining an Associate Degree. High schools create articulation agreements with interested colleges/universities, stipulating which high school courses the students must successfully complete for each two-year program the college/university offers. Upon graduation from high school, these students are automatically admitted into the appropriate two-year program.

2.0 Residence Camp

In the summer of 1999, Penn State Erie, The Behrend College hosted a week long residence camp for Tech Prep students interested in Engineering Technology. The purpose of this camp was for the students to interact with the Penn State Erie Engineering Technology faculty and students. High school students learned the differences between engineering and engineering technology, the type of jobs are available, the high school courses that would benefit them the most, and the financial aid and scholarships are available. They also experienced hands on activities in Electrical Engineering Technology (EET), Mechanical Engineering Technology (MET), Plastics Engineering Technology (PLET) and manufacturing processes. The camp was funded by grant money, therefore, the only cost to the student was transportation to and from camp.

3.0 Manufacturing Processes and Design

The theme of rocketry was used to tie all of the activities together. Monday morning the students participated in one of two assembly lines. Assembling Estes Alpha rockets was chosen for one of the assembly lines and is shown in Figure 1. Companies were formed to make the tasks a little more relevant to industry. The main company assembled the rockets, but sub-contracted work out to smaller specific companies.

The students learned about stream-lining jobs, such as designing and making jigs and fixtures. They were to use problem-solving skills when necessary. Quality control and testing for stability were also important factors in creating the rockets.

We discussed whether they liked working with their hands, coming up with ways to streamline the process, solving problems, etc. They were asked if they wanted to do assembly line work for the rest of their lives? If not, what other options of working with their hands are available to
them. After lunch, the students launched the rockets and measured how high each rocket went. Preparation for the rocket launch is shown in Figure 2. The students were then informed of the rocket design competition at the end of the week. The announcement of the design competition was used as a lead-in to a presentation on basic rocketry principles, such as aerodynamics and propellants. In the evening, the students used the information they learned during the day to practice using rocketry software, such as wRASP™ and VCP™. After successfully arriving at the answers, the students were allowed to start working on the competition project. They were to work in teams of two and create a single stage rocket using parts from the Estes Designer’s Special kit provided by the instructors. The teams were to predict their apogee altitude (AA) and distance downrange (DD). The team’s prediction arriving closest to the actual AA and DD would win the contest. The quality of their working drawings, craftsmanship and paint design were also judged.
3.1 Igniter Switches

In the second assembly line, students were assigned to four companies and which would construct an "Electron Beam Launcher" (EBL). The assembly line and schematic are shown in Figures 3 and 4 respectively. By the end of this session, these students built and tested 24 EBLs. Each student at the end of the camp took one home as a souvenir. Three companies provided subassemblies to a company that assembles and tests the final product. Because of the quantity that was being manufactured, the students had to cooperate and stay focused. EET faculty and Mr. Matt Jones, an EET student, provided guidance and supervision to the students during the entire process.

Three subassembly companies worked in parallel to reduce the time-to-market product. One company provided a finished 16 foot cable with alligator clips. This required the students to measure the length, strip and tin wire ends to specifications and soldering of alligator clips. Assembly procedures and soldering instructions were provided to the students. Students were asked to determine the best way to measure lengths and the easiest way to solder these components. A fixture was also provided to the students for the soldering of the alligator clips. The finished product was used as the cable that would connect the EBL enclosure to the rocket engine igniter. The cable length complies with the official Model Rocketry Safety Code of the National Association of Rocketry and the Model Rocket Manufacturers Association.

Another company had to assemble the safety key and launch-rod safety cap. Both these components are safety code requirements. The safety key must be removable and in series with the launch switch. The safety cap is placed over the launch-rod while not in use to offer eye protection. The safety keys were constructed from 1/4" phono plugs. These plugs required the connection lugs to be shorted. Students were asked what would be the easiest way to solder these components. Finally, the safety cap was attached to the safety key with a string.
A third company had to drill holes in the enclosure lid for the mounting on the phono jack, LED and launch switch. Students were asked what would be the easiest, fastest and most accurate way of accomplishing the task. A fixture was provided to the students so that they could drill 1/8 inch to 3/8 inch holes.

The last company took all the assemblies and integrated them into the final product. This was the most challenging of all tasks. Two stations were established. One required the wiring and soldering of all the components. The other conducted electrical testing. Two electrical tests were performed. One verified that a current less than 20 mA was provided when the alligator clips were shorted together. This was to ensure that an igniter does not go-off accidentally. The second test verifies approximately 2 A is delivered momentarily when the launch button is pressed.

Considering the students were not expected to have any electrical experience, they did very well. They learned rapidly the reading of a wiring diagram and the use of wire strippers, soldering irons and digital multi meters. There was a very high yield rate of the igniters and those that failed were corrected.

3.2 CAD

Students were introduced to Computer-Aided-Drafting (CAD) using the solid modeling package SolidWorks®. Each student modeled the Alpha rocket parts, completed detail drawings and assembly drawings. During the evening session, the students were shown how to edit these drawings to make a set of working drawings for their competition design.

With an understanding of solid model creation using a 3-dimensional CAD system, the students were shown the CAD model for an Alpha rocket carrier. With this in mind, they moved to the rapid prototyping session where they saw a hard model of this part being created using a CNC router.

3.3 Rapid Prototyping and Manufacturing

Students were introduced to both additive and subtractive methods of the rapid prototyping
process. This introduction emphasized the requirement of producing an error-free CAD model before using the rapid prototyping process.

Three additive processes were covered. Sterolithography (SLA) with a laser was discussed. Physical parts used to help explain the process included a 3-D model puzzle of Darth Vader’s head. These puzzles are common in toy stores and illustrate the layering process common to all additive systems. A SLA part of a boat was also used so the students could examine properties of an actual model. This part was finished to various degrees so a discussion could be initiated on the possibilities available without human intervention and on required hand finishing.

Laminated Object Manufacturing (LOM), a process where paper is laminated together and a laser is used to cut the outline of the shape was the next methodology covered. Samples of the build paper used for making different types of parts, as well as models in both the finished and partially finished states were displayed. Finally, a desktop (3-D printing processes) system, such as Sanders and Z-Corporation was discussed. Parts that were physical models of mathematical functions that could not be produced in any other way were used as example parts describing this technology.

Subtractive methods using Computer-Numerically-Controlled (CNC) technology was then covered. Advantages and disadvantages of this methodology were explained. Tool path generation from an existing CAD model was discussed. The rocket holder was used as a demonstration model and the simulation of the tool paths was shown using transparencies. Students were shown the computer generated output file (G Codes). This was used as an introduction into what could be done at a high level. To allow the students to actually see that they could “teach” a machine tool the operation to perform, the students were then given a brief lesson in G Code programming. Simple concepts for programming a three-axis CNC machine were covered. This included rapid, linear and circular interpolation and the difference between absolute and incremental positioning.

With this background, the students were given engineering paper and asked to sketch out a simple design or their initials. They then wrote G Codes that were used to carve this data into a three inch by five-inch piece of extruded polystyrene using a 3/8 inch ball end mill with a CNC router. These G Codes were entered into a text file using a word processor and the data saved to a disk.

After moving to the manufacturing laboratory, each student had the opportunity to load their work piece into a fixture on the CNC router, load the G Code file into the controller of the machine and watch a simulation of the tool path on the computer screen. At this point, simple corrections were made to the program and re-simulated. When this was finished, the data was sent to the machine tool and the part cut.

When all the students had finished machining their individual parts, this session concluded with a demonstration of machining the rocket holder. Students where shown how to set offsets for the machine relative to the position of the unfinished stock. They then witnessed the roughing passes made to get the stock to approximate size. The finishing passes were then started and since this was a 3-D contouring operation, they could see that the only way to have produced these tool paths was with the aid of a computer.
3.4  Plastics Processing

Students were introduced to the major plastic processes including injection molding, extrusion, blow molding and thermoforming along with a number of other processes. Three hands-on activities were provided for the students that were to culminate into the construction a rotating rocket model stand. Student groups were assigned to the three different workstations that ran simultaneously.

Thermoforming is a process where a sheet of plastic is heated to its softening state and formed around a one-piece mold using air pressure or a vacuum. The thermoforming process was first introduced to the students from the standpoint of design and mold construction. The forming process was then demonstrated on a machine and the trimming and decorating options were discussed.

The thermoforming activity continued from the presentation on prototyping and manufacturing given by the Mechanical Engineering Technology staff. A thermoforming mold for a rocket stand had been designed and machined by the MET staff out of a heat resistant modeling material. The mold had been used as a working example of the CNC programming and machining capabilities which the students were able to experience themselves. The mold had been completed by coring out a vacuum chamber and drilling the .030 inch diameter vacuum holes from the vacuum box to key points upon the surface of the mold. It was then attached to a base for mounting into the thermoforming machine.

The students had the opportunity to vacuum form at least one rocket stand, shown in Figure 5, from impact polystyrene sheet. They also were shown how to trim the excess sheet from around the part. After trimming their parts they decorated their rocket stands with colored ink markers.

![Figure 5. Vacuum Form Rocket Stand and Mold](image)

The injection molding process is the most common plastics process used in the world. It is especially useful for producing large volumes of complex parts with short cycle times. The students had the opportunity to observe this process by running a press that was set up with a mold for making gears, shown in Figure 6. The fine tooth gears were molded out of polypropylene in a four cavity, three-plate mold that contained a hot sprue bushing. It was pointed out to each group...
how the plastic flowed through the mold and how the parts were automatically deleted from the runner upon ejection from the mold.

![Figure 6. Injection Molding Press and Gears](image)

A machining and assembly station was set up to fabricate a rotating model stand. Each student was given a block of wood and some wood screws to use with the gears that they had molded. The objective was to make a gear train on top of the wooden base so the rocket model stand could be rotated to form a working display. When the student turned a crank, the energy was transmitted through four or five intermeshing gears to rotate the stand.

The students had to use a steel drilling fixture to drill out the center of the gears to adapt them to their bases. Each student got to choose the type of gear train pattern that they wanted to use, after which, they laid out the center hole patterns on their bases and drilled the pilot holes into the wood. The gears were mounted to the wood base with the wood screws to form a gear train pattern of the student’s choice. The final step was for the students to construct an adapter plate with which to mount the rocket base to the primary gear on the gear train stand.

3.5 Electrical

Students were introduced to basic DC circuit fundamentals through lectures and laboratories. The lecture was divided into three parts: field of EET, circuit fundamentals and electrical ignition system.

First, the field of EET was described to the students. The following topics were discussed: the EET field, the difference between EE and EET, degrees offered in EET, the engineering team, specialized EET courses, job placement, types of EET jobs and salary range.

The second portion of the lecture introduced the students to electrical principles they would need in the laboratory that was to follow. We discussed atoms, voltage, current, conductors, insulators, resistance, Ohm’s Law, series circuits and parallel circuits.

The third portion of the lecture described the igniter switch operation that was constructed on the first day of the camp. The schematic was discussed, as well as the purpose that all the
components served. The components of the igniter are: battery, safety key, LED, resistor, push button switch, wire, alligator clips and igniter.

Finally, the students were taken to the laboratory to conduct two hands-on experiments. The first illustrated the resistance of series and parallel circuits. The objective of this experiment was to become familiar with the methods for calculation of an equivalent resistance for resistances in series, in parallel and in series-parallel circuits. The second was on voltage and current measurements. The objective of this experiment was to become familiar with the usage of the voltage and current settings in circuit analysis. Students conducted simple resistive DC circuit experiments using a bread board and a DC power supply.

3.6 Wind Tunnel

An elective morning session was offered involving wind tunnel testing of their individual rockets. The session began with a lecture outlining the importance of drag forces on flight capabilities. The presentation included the effects of surface finish, frontal area, velocity and air density as they effect viscous drag on a body immersed in a flow field. The session was completed by testing each team’s rocket in the wind tunnel and calculating a coefficient of drag, which they used to refine their flight predictions for the design competition.

3.7 Design Competition

The camp week activities culminated in a competition in which each team launched the rocket of their own design. Figure 7 shows the students working on their rockets. The rockets were checked by one of the counselors for stability and safety prior to the competition. At the launch field, each team entered their prediction for apogee altitude (AA) and distance downrange (DD) before they were selected in random order to make their launch. Two independent observers measured the rocket altitude with hand held devices calibrated for such measurements. An additional team of judges measured the recovery distance from the launch pad with a track and field tape measure. The launch director computed the score using the metric: \( \text{SCORE} = (\text{predicted AA} - \text{actual AA}) + (\text{predicted DD} - \text{actual DD}) \). With this measure, the lowest score, which corresponds to the best predictions of their actual flight, identified the winning team.
4.0 Conclusion

At the end of the week students were given questionnaires to provide feedback of their experience. We learned that the students were satisfied and interested in many of the technologies available. Students liked to work on the computers and the many hands-on projects. Thirteen out of the twenty-five have expressed an interest in returning next year and working as assistants. The week was fully scheduled and some expressed they did not have sufficient time to complete some of the projects. This camp is still in progress and further follow-up and tracking of students is required to fully evaluate its effectiveness. However, the model rocketry theme provided a means to pull together various disciplines, present technology and keep it fun and interesting for high school students.

5.0 Future Recommendations

The design and implementation of this outreach project revealed several opportunities for improvement. The area of chaperoning could be improved. Since the students lived on campus, it was important for some form of monitoring of the students. Two faculty were responsible for the students. This proved to be a burden, since the faculty had to get up the next day and teach as well. One suggestion is to market the camp to high school teachers and give them the responsibility for the students from their school. The teachers would attend all camp activities and in return receive in-service credits from their school district. Another suggestion would be to change part of the competition. Instead of judging which rocket lands closest to a predicted spot, judge which rocket lands closest to the launch site. Another suggestion would be to keep lectures as short as possible. The students enjoyed working with minimal instruction then learning on their own. Perhaps breaking lectures into smaller parts and teaching throughout the hands-on projects would be more effective. Finally, follow-up with the students that would like to help next year and find out what they liked most. Then give them the opportunity to make changes to the schedule.

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