Promoting Engineering at an Inner-City Chartered School

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Abstract – Tech High, an Atlanta inner city charter school, was created in 2003 in order to prepare all graduates to succeed in college or a technical career. The goal of Tech High School is to maximize the learning of every student by having project-based activities and real world applications, making learning relevant. The promotion of engineering is done through several different classroom projects such as: the conversion of an old motorcycle into an electric vehicle; altering a diesel car to run off of vegetable oil; and the creation of a solar collector, which will allow a house trailer to be converted to a high efficiency off-the-grid residence. The promotion of engineering as a career choice is important because it is essential for a number of industries from healthcare to sustainable energy; however, developing engineering courses for high school students is nontrivial and the lesson's learned will be addressed.

Keywords: High school, engineering course, sustainable energy projects

INTRODUCTION

Tech High School was created and designed as an innovative charter school, approved by the Board of Atlanta Public Schools and established by the State Board of Education in 2003. Tech High was born out of the determination of respected business, community, and educational leaders in the metropolitan Atlanta area to deal with the student performance needs of Atlanta and the shortage of highly skilled workers in Georgia. In order attend Tech High, there are no special academic selection criteria for incoming students. Tech High operates on the assumption that all students who are willing to work hard and apply their talents to the academic requirements of Tech High, will, if challenged by interesting curriculum and dedicated instruction, achieve a high level. The demographics of Tech High are as follows: 96% black students, 4% white students, and 66% of the students are eligible for free/reduced lunch. Because Tech High is a charter school, it has flexibility to implement innovative curricula such as the Center for Sustainable Technology (CST). One of the goals of CST is to promote engineering as a career option through several different classroom projects such as: the conversion of an old motorcycle into an electric vehicle based on Litestar, an automotive design by Jim Bede; altering a Mercedes diesel car to run off of vegetable oil; and the adaption of an enclosed trailer into a workshop. Later in the year the students will work on solar collection and concentration, which will allow a house trailer to be converted to a high efficiency, off-the-grid residence. Promotion of engineering as a career choice is not only done through these hands-on projects but also through the involvement of Georgia Tech students through the Student and Teacher Enhancement Partnership (STEP) NSF GK-12 program.

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COURSE CONTENT

The goal of the engineering course at Tech High is to provide the necessary foundation for further courses in engineering at the university level by introducing the students to the history of engineering and the process of design along with project management and implementation. This course employed a team based approach where cooperation and contribution to the team effort was essential. It was based-on a dozen different projects that all fall underneath the Center for Sustainable Technology. Three of the projects currently being implemented are: the conversion of an old motorcycle into an electric vehicle; altering a diesel car to run off of vegetable oil, and the adaption of an enclosed trailer into a mobile workshop and lab. In the first semester of this course there were 18 students, 3 lower academy students and 15 upper academy students. The lower academy students are in their first and second year of study, and the upper academy students are in their third and fourth year. The students in this class were divided into three different groups and were split so that each group had at least two upper academy students. The hope was that the upper academy students would mentor the lower academy students not only from an academic standpoint but also to help ensure that they stayed on task. The students were then assigned to one of the projects previously mentioned. They then worked on their assigned project for approximately three weeks prior to switching to another project. By switching projects, not only would all students would have the opportunity to learn different skills, but also the importance of effective communication would be stressed because each team would have to inform the next group as to what needed to be completed next. Therefore throughout this course, the three main topics that were covered included: project planning, design development, and project execution.

Project Planning

At the beginning of the year, the students were taught project planning by preparing task lists along with estimates for the duration of each task. From this activity, the students were able to see variations in the estimated time, and then discussed the reasoning for these variations such as the assumptions that were made. For instance, the students were to estimate the time and duration required to fix the windows in the car. Some students assumed that only a fuse would need to be replaced, while others thought that a new motor would need to be installed. After preparing the short task lists for several weeks, the students were then asked to prepare a Gantt chart for their project for the next month. Because of the previous discussion with the weekly lists, the students were able to see how a project could be split into tasks and the students were starting to understand the information needed to make accurate time estimates. This skill is not only necessary for completing engineering projects but could also be used for one's own weekly planning and is one step in becoming a good time manager.

Design Development

Along with project planning, the students also learned how to use inventor software. Inventor is a computer program, similar to AutoCAD, which allows students to create three dimensional drawings. Each team was to create different parts in their projects. For instance, the electrical vehicle team was supposed to draw the frame for their vehicle. One issue with this task is that there were not enough computers for each person to work on their own part. Therefore, there were students just sitting around, and they weren't really helping each other. Next time in order to make sure that everyone was doing their fair-share, a timer would be set so that every five minutes a new person would be responsible for driving the computer, which would ensure that everyone learned how to draw parts not just the computer savvy students. While developing the student's computer modeling skills, the students were also required to build paper models of various items from airplanes to buildings in order for them to understand the importance of modeling.

Project Execution

Throughout the semester, there were also designated days in which the students would get to work on their project for the entire hour. By having the upper academy students grouped with the lower academy students, the idea was that the upper academy students would be mature enough to know how to act regardless of whether the teacher was looking over them. Since there is only one teacher in the classroom, it is impossible to look over and help with all three projects at once! Although the upper academy students were staying on task for the most part, they had little to no control over the lower academy students nor did they particularly care that their teammates were not paying attention. There were several instances when a lower academy student was caught misbehaving such as throwing berries, writing profanity, or "attempting" to cut down trees using hammers. As always with younger aged high school students, some days they were more behaved then others. In order to help ensure they stayed on task, part of their grade in the course was based on a peer evaluation of their work effort. If the students seemed to be more off

task then normal, they were given a self evaluation paper to fill-out. It was amazing how on-task the students were after filling-out the self-evaluation! Next semester, there is plans to keep selected lower academy students in the team engineering class, while the majority of the lower academy students will be removed and placed in a structured class where they will be under direct supervision and given more concrete tasks. The goal of lower academy course will be to prepare the students for the team oriented class.

State Performance Standards

Besides the tasks above, there were also lecture days in which the students were taught new information that was pertinent to the project at hand. For instance when fixing the fuses in the car, the students learned about voltage and resistance measurements, along with how to calculate the effective resistance for resistors in series and parallel. They also learned about thermal dynamics such as how heat exchangers work and a little bit about entropy and enthalpy. There were also various other lectures, but these were just a few. Overall the students are supposed to master the concepts and applications for the following State Performance Standards:

ENGR-STEM1-Students will recognize the systems, components, and processes of technological system.

ENGR-STEM2-Students will identify the impact of engineering and technology within global, economic, environmental, and societal contexts.

ENGR-STEM3-Students will design technological problem solutions using scientific investigation, analysis, and interpretation of data, innovation, invention, and fabrication while considering economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability constrains.

ENGR-STEM4-Students will apply principles of science, technology, engineering, mathematics, interpersonal communication and teamwork to the solution of technological problems.

ENGR-STEM5-Students will select and demonstrate techniques, skills, tools, and understanding related to energy and power, bio-related, communication, transport, manufacturing, and construction technologies.

ENGR-STEM6-Students will enhance reading by developing vocabulary and comprehension skills associated with text materials, problem descriptions, and laboratory activities associated with engineering and technology education.

ENGR-STEM7-Students will develop leadership and interpersonal problem-solving skills through participation in co-curricular activities associated with the Technology and Student Association.

GRADING METHOD

This engineering course is graded using a mastery method. The goal of this method is to have the amount of content covered being a fixed parameter instead of time. The grades for this course are broken down into the following percentages: work ethic grade (10%), subject section test grades (20%), subject section preparation (5%), projects/labs (40%), peer/self evaluation (15%), and final exam (10%). Each section test typically consists of the following packet of work: a section pretest, completed class notes, and homework assignments. In order to take the section test, all section preparation work must be completed first. Students must score a 90% or higher on the section test to complete a section and earn the points for the section. Students will be allowed to makeup the section test for a reduced maximum possible grade, but the 90% or higher is still necessary for completing the section and receiving the section points (Table 1). The ultimate objective of this process is to help students take responsibility for their learning. If a student works diligently and consistently through this process, the need for repeated assessments will diminish with time. Students will be given an opportunity to internalize the responsibility through adequate preparation and demonstration of learning.

Table 1: Mastery Grading Policy

	Test Score	Percentage Earned
First testing	90% or higher	100%
Second testing	90% or higher	87.5%
Third testing	90% or higher	75%

STEP PROGRAM

The Student and Teacher Enhancement Partnership (STEP) is an NSF-sponsored GK-12 program whose main objective is to use the exceptional expertise available from students at Georgia Tech to assist in increasing the mathematics and science performance of Atlanta-area high school students. Currently there are two STEP students at Tech High, an undergraduate and graduate student. These STEP fellows typically come to Tech High once a week to share their passion for math, science, and engineering with the next generation. These STEP students are role models for several of the students. While in the classroom, they show the students that new areas in engineering are constantly emerging. For instance, one of the STEP fellows brought in items from her research and discussed the creation of ultrasound transducers for medical imaging using a microelectrical mechanical system (MEMS) process. This presentation not only ignited the curiosity of the students but also corrected some of the misconceptions the students had in which they considered math and science as old-fashioned, complicated, and irrelevant. Next semester, the STEP fellow is planning on taking the high school students on a field trip to Georgia Tech for them to not only see what other research is currently being performed but also in hopes to inspire some of the students to purse a degree in engineering, which will help to ensure a bright future for our society.

FUTURE PLANS-CENTER FOR SUSTAINABLE TECHNOLOGY

Sustainable technology has been defined as technology that provides for our current needs without sacrificing the ability of future populations to sustain them. In other words it is meeting the needs of today without compromising the ability of future generations to grow and prosper. Therefore, the development of the engineering course previously described is one step in reaching the greater goal of developing a center for sustainable technology (CST) at Tech High. The main focus of CTS is to engage students with hands on project based activities. Some of the projects that will be undertaken at CST include solar collection, solar concentration, sustainable gardening, methane and hydrogen production, and the conversion of a house trailer to a high efficiency, off-the-grid residence. All of these projects are related in some way to sustainability in the areas of energy, transportation, housing, and food production. The overall goal for CST is to educate students about the challenges they will have to overcome in the future. Therefore, the students will analyze the factors involved in producing sustainable technologies such as the economic costs and feasibility.

In order to enhance the learning experience of the students activity involved with CST, the following items will be included whenever possible:
-Application of mathematics to the problem
-Reading in the content area, including standard resources as well as current advances and research in the area
-Design using 3D solid modeling software
-Conceptual freehand sketching
-Conceptual modeling using robotic kits
-Project management using Gantt Project or other software

SUCCESS OF TECH HIGH

The success of Tech High school can be measured via the students test scores and number of graduating seniors who went into STEM-based college majors. During the school year, the students are required to take statewide assessments due to the No Child Left Behind Act. These tests measure the student's year-to-year achievement along with demonstrating the school, school districts, and states teaching performance in the subject areas of reading, science, and mathematics.

In order to meet adequate yearly progress (AYP), each school must meet the following criteria: 95% participation, academic performance, and second indicator which includes items such as percentage of graduating students and the attendance rate. Several Atlanta-area schools did not meet the requirements necessary to achieve AYP; however, Tech High School has met adequate yearly progress every year since its creation (4th year in a row). Listed below are some of the statistics from the 2008 AYP test:

-Students meeting and exceeding science standards, 73.9%
-Students meeting and exceeding mathematics standards, 87.2%
-Students meeting and exceeding all standards, 84.3%
-High school graduation rate, 91.5%

These test scores demonstrate the success of Tech High. Another indicator of its success is the number of students attending college. More than 90% of the 2007 graduating class is attending college, and most of the students are pursuing a science, mathematics, or engineering major.

CONCLUSION

As has been shown, promoting engineering at the high school level can be a challenging task but with patience and determination it can be done. The students in the engineering course previously described are really starting to take their own intuitive in their projects and are excited to come to class. Many of the students have commented that they cannot wait to go to college to get their degree in engineering, which is really rewarding. Therefore, overall the engineering course has been a success despite the usual classroom interruptions and misbehavior.

Ashley Bernal

Ashley Bernal is a mechanical engineering doctoral graduate student at Georgia Tech. Her area of emphasis is in microelectrical mechanical systems (MEMS), and she is currently working on developing a high resolution ultrasound device for medical imaging. Her activities include being a member of the mechanical engineering graduate association (MEGA) and the Gamma Beta Phi honor society. She is also a Student Teacher Enhancement Program (STEP) fellow and is an instructor for the Kids Interested in Discovering Science (KIDS) club. She was recently awarded "Who's Who Among American College Students." Prior to graduate school, she received her bachelor's degree in mechanical engineering with an emphasis in aerospace from Rose-Hulman Institute of Technology and worked full-time for Boeing's Integrated Defense Department.

Alan Gravitt

Alan Gravitt is a physics, physical science, and engineering teacher at Tech High. He is the coach for the Tech High RoboTitans and is the Student Teacher Enhancement Program (STEP) coordinator. Previously, he was the vice president and founder of Tiberian Technologies, where he developed a process for producing titanium diboride. He also founded ADA, a robotic automation company, and ICA-TriNova, where he organized a subsidiary of ICA-Pictureworks focusing on implementation of the software in an education environment. He also founded the Professional Association of Georgia Educators (PAGE). He received his bachelor's degree in physics at Georgia Institute of Technology, and received his master's degree in science education from Georgia State University.