

## **Incorporating Engineering Concepts in the Middle School Science Classroom**

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### **Abstract**

Hands-on engineering based lessons have been developed and implemented in middle school science classes through the Vanderbilt-Meharry-TSU NSF Graduate Teaching Fellows (GK-12) program. This paper presents laboratory activities designed to incorporate engineering concepts into middle school science classrooms. The engineering based labs were designed to enhance and stimulate middle school students' interest in science, technology, engineering, and mathematics (STEM) concepts. Lessons are focused on increasing students' awareness of engineering in daily tasks. Career opportunities relating to the engineering lesson were presented. The importance of effective teamwork, critical thinking, problem solving, and sound technical communication are emphasized. These engineering labs are available for future use by the partner teacher and the GK-12 program.

### **Introduction**

The National Science Foundation Graduate Teaching Fellows in K-12 Education Vanderbilt-Meharry-Tennessee State Program is now in its fifth full year<sup>1</sup>. The major focus of this program is to partner graduate teaching fellows (GTFs) with Nashville middle school science teachers. This GK-12 Program is a partnership between three educational institutions of higher learning, all within a five-mile radius of each other in Nashville, Tennessee.

The 2004-2005 school year brought together 15 Metropolitan Nashville Public School teachers and 11 graduate students in a collaborative effort to improve science instruction and provide opportunities for middle school students to work with scientists. In addition, one undergraduate student from Vanderbilt University assists teachers in two schools to increase the frequency and quality of laboratory activities.

GTFs focus on working with partner teachers to develop and implement hands-on, inquiry-based activities, providing classroom demonstrations, assisting with tutoring students, and directing student research projects. A total of 49 fellows and 56 teachers in 18 schools have been included in the Vanderbilt-Meharry-TSU program to date. In addition to the GTF component, an undergraduate (UGTF) program is also included with

twelve exemplary undergraduate science majors assisting in the assembly and design of kits for classroom activities. This program has had a major impact on all target audiences - GTFs, UGTFs, partner teachers, and students. In high demand by Nashville teachers, the program has implemented on-going professional development for GTFs and teachers. Student achievement test scores have increased, and attitudes toward science have improved.

The Vanderbilt-Meharry-TSU GK-12 program consists of four major components: (1) Summer Orientation Workshops for GTFs and Partner Teachers, (2) The Academic Year Program, (3) Weekly GTF Seminar, and (4) Evaluation and Assessment.

1. Summer Orientation Workshops for GTFs and Partner Teachers: GTFs and partner teachers spend four weeks developing their partnering relationships and planning lessons and activities for the upcoming academic year. During summer 2004, fellows and teachers participated in team-building activities, developed hands-on and inquiry-based classroom activities, and demonstrated lessons to teachers and GTFs.
2. The Academic Year Program: GTFs and partner teachers were selected in the spring of the preceding year. Each GTF was assigned to a school team with partner teachers for a period of one or two semesters. GTFs spend a minimum of ten teaching hours per week (two full school days) at the school and five hours per week in preparation time. GTFs focus on working with partner teachers to develop and implement hands-on, inquiry-based activities, provide classroom demonstrations and activities, and assist in tutoring of students and directing student science fair projects. In the current program year, the focus is entirely on the middle school level.
3. Weekly GTF Seminar: In addition to the two days per week working in the schools and five hours of planning time, the GTFs attend bi-weekly 2-hour seminars with the program coordinator. The seminar includes presentations from other program personnel, guest speakers from the three university partners, and discussions concerning education methods. The seminar is designed to provide a forum for feedback from the GTFs, to follow their progress in the program, provide a reflection time for the teaching experience, and acquire feedback from the fellows to improve the program design for future cohorts of fellows. These sessions are designed to give the GTFs assistance in any activity related to the classroom. GTFs are also responsible for preparing and presenting lessons on effective instructional strategies. Some of the topics have included: process skills, constructivism, cooperative learning, learning styles, inquiry, and effective questioning strategies.
4. Evaluation and Assessment: Extensive evaluation tools such as interviews of GTFs, partner teachers, and students, pre and post content assessments of students, classroom observations, videotaping of GTFs, and interviews with

research advisors and principals continue to be instructive for program improvement.

### **General Laboratory Experience Model**

A general laboratory experience model has been developed to maximize the impact of laboratory experiences on students. Since students have many different learning style preferences, it is imperative to engage students with a variety of instructional methods. For this reason, many of the laboratory experiences proceed in the following manner. The laboratory experience can generally be segmented in four broad parts: (1) Introduction, (2) Hands-on Activity, (3) Discussion, and (4) Journaling.

1. Introduction: In some cases if the laboratories are lengthy, partner teachers will present the introduction segment the day before the GTF comes.
  - a.) Guided Inquiry: Students are typically asked questions about topics that are familiar to them and related to the laboratory experience. The GTF and partner teacher work to incorporate the students' answers in the laboratory experience.
  - b.) Initial Information: Most labs have handouts for students to record relevant definitions, formulas, goals, and specific information needed for the laboratory experience.
  - c.) Explanation: The GTF and/or partner teacher reiterates how the guided inquiry discussion, definitions, and formulas relate to the laboratory experience.
  - d.) Demonstration: The GTF and/or partner teacher will demonstrate the concept of the laboratory experience.
2. Hands-on Activity: Students are typically in groups of three or four. In some cases, students will work in pairs. Most of the laboratory experiences are structured to encourage scientific reasoning and mathematical computation. Students construct charts to record data and graphs to display data. The scientific method is primarily followed throughout the process.
3. Discussion: In the discussion segment, students ask questions, present observations, data, and results. Students are also informally or formally quizzed about what they have learned.
  - a.) Career Exploration: At least two or three careers related to laboratory experience are discussed.
  - b.) Further Exploration: Students are provided opportunities to further explore the topic outside of class.

4. Journaling: Each student is provided a journal to record laboratory experiences. At the end of each laboratory experience, students are asked to record what they learned from the laboratory experience. Students are encouraged to display their understanding through diagrams, graphs, writing, and/or pictures.

Most of the hands-on material is obtained through Vanderbilt Student Volunteers for Science (VSVS)<sup>2</sup>. Vanderbilt Student Volunteers for Science (VSVS) is a science volunteer organization at Vanderbilt University composed of undergraduate, graduate, and medical students. This organization provides hands-on science related kits with the necessary material and lesson plans.

### **Engineering Related Laboratory Experience**

The laboratory experiences Energy Conversions and Roller Coasters and Bottle Rockets have been placed into the general laboratory experience model.

#### Energy Conversions and Roller Coasters

1. Introduction: Because Energy Conversions and Roller Coasters can be a lengthy lab, the partner teacher usually presents the introduction segment the day before the GTF comes.
  - a.) Guided Inquiry: Students are asked about energy, the Law of Conservation of Energy, forms of energy, states of energy, how does a roller coaster work, have you been on a roller coaster, what must be considered when designing roller coasters, and who designs roller coasters.
  - b.) Initial Information: Students are given the definitions of energy, the Law of Conservation of Energy, potential energy, and kinetic energy. The forms of energy and states of energy are given to students. The goal of this laboratory experience is to study the relationship of height to potential energy and the resulting kinetic energy.
  - c.) Explanation: Students will assume the role of roller coaster designers working on an engineering design team. The design team's task is to design a roller coaster with three hills. The first hill must be at least 4 feet from the ground. The first hill counts as one of the three hills. There are two competitions taking place. One competition involves the roller coaster car traveling the fastest. The other competition involves the design team creating a roller coaster design with the most total centimeters in height of the three hills. Each design team will receive a 12-foot inch thick clear polyvinyl tubing to serve as the roller coaster track, 3-4 BBs to serve as the roller coaster car, masking tape to hold the roller coaster track down, tape measure, observation sheets,

and a Styrofoam cup. After the BB is released through the tubing, the Styrofoam cup is used to catch the BB on the opposite end of the tubing. A successful roller coaster is one in which the BB travels from beginning to end without getting stuck in the tube.

- d.) **Demonstration:** A toy racecar track set is used to demonstrate how and where roller coasters achieve maximum potential and kinetic energy.
2. **Hands-on Activity:** Students are typically in groups of three or four. On the student's observation sheet, students will be asked to create an initial plan to construct a successful roller coaster. As a team, students will determine which design to attempt first. Student use the wall space in the hallway of the school building. Once students have designed their successful roller coaster, they will take the measurements of the hills, and sketch the final roller coaster design.
  3. **Discussion:** Students are asked to answer the following questions:
    - What things affected whether your roller coaster worked or not?
    - What happened when you made a steep hill?
    - Where did the BB have the most potential energy?
    - Where did the BB have the most kinetic energy?
    - What happened to the potential energy as the BB went from the top of the hill to the bottom of the hill?
    - Using the roller coaster as an example, put in your own words what "conservation of energy" means.
    - a.) **Career Exploration:** Careers in designing roller coasters and physics are discussed extensively.
    - b.) **Further Exploration:** Students can be challenged to find out what would someone need to do to become a roller coaster designer, and where can you work as a physicist.
  4. **Journaling:** Students will attach their observation sheets to the journal and write about what they learned from the laboratory experience.

### **Bottle Rockets**

1. **Introduction:** Because of the length of the bottle rockets laboratory, the teacher will typically introduce the concept of the laboratory the day prior to the laboratory day.
  - a.) **Guided Inquiry:** Students are asked about force, air pressure, Newton's laws of motion, what happens when you hit a baseball, what

happens when the wind rustles leaves, and what might happen when air is pumped in a sealed bottle.

- b.) Initial Information: Students are provided with the definitions of force, air pressure, inertia, and Newton's Third Law of Motion. The goal of this laboratory is to study Newton's Third Law of Motion with bottle rockets.
  - d.) Explanation: Students will assume the role of rocket designers working on a rocket launch team. Each student team will be provided with a 2 liter drink bottle, 20 oz. drink bottle, water, string, tape, stop watch, and goggles. As a team, students will test each bottle with varying amounts of water. As a safety precaution, the GTF will operate the bicycle tire pump with pressure gauge. The string will be taped to the tip of the rocket in order to get an approximate height of the rocket at the peak of its launch. Students will record the flight time, launch pressure, level of water, and approximate peak height of rocket.
  - e.) Demonstration: An inflated balloon that is not tied is attached to a straw with tape. A string is treaded through the straw on the inflated balloon. The partner teacher will hold one end the string and the GTF the other end. The GTF or partner teacher will release the inflated balloon. Before its release, students will determine what would happen. This is a demonstration of Newton's Third Law of Motion.
2. Hands-on Activity: Students are typically in groups of three or four. Students will test their bottle rockets and record the data on charts. From the recorded data, students will plot the data on graphs. Students will note their findings.
3. Discussion: Students are asked to answer the following questions:  
For each of the questions below, list the type of bottle used, level of water, amount of pressure, flight time, and approximate height.
- Which launch traveled the greatest height? Why?
  - Which launch had the least height? Why?
  - Which launch had the greatest flight time? Why?
  - Which launch had the least flight time? Why?
- e.) Career Exploration: Careers in rocket design and physics are discussed extensively.
  - f.) Further Exploration: Students will be encouraged to find out about different types of rockets, what types of fuels are used in rockets, and what is the significance in the shape of the rocket.
4. Journaling: Students will record the data in their journals and will write about what they have learned from the bottle rocket laboratory experience.

## Bibliography

1. National Science Foundation Vanderbilt-Meharry-TSU NSF Graduate Teaching Fellows (GK-12) program, <http://www.vanderbilt.edu/GTF/index.php>. Last accessed January 3, 2005.
2. Vanderbilt Student Volunteers for Science, <http://www.vanderbilt.edu/vsvs/index.htm>. Last accessed January 3, 2005.

## Biographical Information

CORDELIA M. BROWN is currently enrolled as a doctoral candidate in the Department of Electrical Engineering and Computer Science at Vanderbilt University. She is a student member of ASEE, IEEE, and NSBE. Her interests include employing learning models to the engineering classroom and laboratory. Cordelia has been a NSF GK-12 Fellow since the 2003 - 2004 academic year.