STEPing into the Classroom: An Alternative Capstone Experience

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This paper describes the experiences of three Electrical Engineering seniors who chose an alternative to a traditional capstone design project; they applied their undergraduate engineering education in high school math and science classrooms as NSF STEP Fellows. *Project STEP: Science and Technology Enhancement Program* is sponsored by the National Science Foundation to promote science, technology, engineering, and mathematics (STEM) skills in K-12 education. Two of the primary goals of STEP are (1) to train future scientists, engineers, or STEM educators to bring their technical backgrounds into the classroom to enable secondary education students to relate STEM knowledge to the world they live in, and (2) to design, develop, implement, and assess hands-on activities and inquiry-based projects that promote authentic learning. The STEP Fellows provide the high school students with direct experience of the relevancy of their education to life, society, and the world, in addition to enhancing math and science curriculum with familiar, real-life engineering and technology examples.

This paper describes how the project meets ABET's capstone design criterion as well as the objectives of NSF Project STEP. Lessons designed by the seniors and their reflections on their experiences are detailed.

1. Overview of NSF Project STEP

Project STEP is a National Science Foundation multi-year project at the University of Cincinnati that supports engineering and education university students as classroom assistants in inner-city high schools. The goals of Project STEP (Science and Technology Enhancement Program) are to educate, nurture, and facilitate science and technology university students into bringing their experiences and knowledge into the classroom and becoming educators. It recognizes that effective student education requires authentic and inquiry-based learning. Students must be able to link the relevance of their education with the events and issues occurring in their community. In addition, students must be able to experience how their education allows them to participate as effective citizens in a technology-driven society. Project STEP will prepare future science and mathematics educators who are capable of authentic teaching.

STEP has three primary goals. The first is to produce scientists, engineers, and secondary science and mathematics educators who are experienced in developing and implementing authentic educational practices into secondary science and mathematics curricula. In addition, these students will be resources to and partnered with secondary teachers to bring their technical background and expertise into the classroom in a meaningful and edifying manner so that the secondary students can relate science, technology, engineering, and mathematics (STEM) knowledge they learn to the world they live in. The second goal is to design, develop, and implement hands-on activities and inquiry-based projects related to an issue or topic pertinent to the students' community as a vehicle to teach STEM skills authentically. The idea is to enable secondary students to experience the relevancy of their education to everyday life, society and the world. The third goal is to encourage secondary students to consider engineering as a field of study in college and as a profession.

Project STEP Fellows are primarily graduate students, but several undergraduate students have participated and used the experience as a capstone design experience. The Fellows are trained by College of Education faculty in a sequence of graduate courses that cover topics including classroom management techniques, lesson planning, instructional delivery, state and national standards, and assessment of student learning. Field practicum allows the Fellows to observe teachers' classroom styles and become acquainted with school culture that may be very different from their own experiences. The Fellows work on STEP activities for approximately 20 hours per week (10 for undergraduates) and spend a minimum of 6 hours per week in a high school classroom. Fellows design, develop, implement and assess lessons throughout the school year and conduct annual workshops for teachers to disseminate their results and share their STEM expertise. Each undergraduate Fellow is paired with a graduate Fellow.

As a capstone design project, the students assist teachers in high schools to integrate real life engineering problems and technology into their curricula. Secondary teachers often do not have the technical knowledge to feel comfortable presenting this material to students, and there are not enough resources of this type available in online lesson plan databases and websites.

2. Overview of Activities of the Fellows

The experiences of three Electrical Engineering undergraduate Fellows are described here. All three students taught in Cincinnati Public Schools secondary schools.

2.1 Nathan Dees

Nathan Dees worked at Western Hills University High School[1] in the academic year 2002-2003. He worked with Tamra Johnson (graduate Fellow) and also completed several lessons independently; some of these lessons were related to aerospace engineering. His lesson called Water Rocket Wizardry included showing the movie "October Sky" and launching water rockets outdoors. The lessons were integrated with both history and mathematics topics that the students were concurrently studying. Nathan describes the experience as follows.

The teachers wanted to upgrade their annual rocket project. They were very influential in what became a week's worth of cross-disciplinary assignments geared around rocketry, with the climax being the launching of students' individually designed rockets.

The project began with an article and discussion on the Cold War in the United States and the way it spurred national interest in the space program. Later in the afternoon, we projected the movie "October Sky" onto a screen in a classroom with the entire ninth grade class gathered. "October Sky" is a story about four high school boys in a small West Virginia coal mining town. While their fates according to the town and their families are to become coal miners themselves, the boys do not wish it to be so. Through intense study and experimentation, the boys design a model rocket which ends up winning a national science fair, and scholarships were awarded to each of them to attend college and leave behind the little mining town and its influences behind.

The next day, we took the students outside for some demo launches of water rockets using plain 2-liter bottles half-filled with water. Using a launching system purchased on the internet and an air compressor that plugged into the cigarette lighter of the history teacher's truck, we pumped 80 pounds of air pressure into the plain 2-liter bottles and then released them. The bottles went up about 40 feet and veered off to the side each time. The students were presented with the real-life problem: How would they modify a plain 2-liter bottle to fly high and straight?

The students began constructing rockets that day using everyday materials we provided. They finished them the next day using spray paint donated by the art teacher. And the following day, each student launched his or her very own rocket. We also took measurements in the process. Teams of four students helped record each rocket's descent time, angle of depression, and horizontal flight distance. Follow-up activities included a report covering design characteristics in relation to flight success, and calculations of the maximum height of the rockets using the measurements taken during the launches.

I had a short talk prepared to help relate the focus back to the real lives of the students, since that was one of the main initiatives of the grant. I wanted to talk about aerospace engineers and how they study and perfect things as common as golf balls and as vital as defense missiles. I had also wanted to lead them through a percent error calculation between their two maximum height calculations and relate it to the percent error allowed for angle of reentry into the earth's atmosphere by a real rocket. The intention was to mention the recent Columbia tragedy and demonstrate the epic magnificence of every single manned space mission and the responsibility engineers and scientists bear. Unfortunately we ran out of time.

On the other hand, many of the students strongly related to the main characters of the movie. The students in "October Sky" felt extreme entrapment from the pressures of their families and the pressures of the town, and many students in any Western Hills classroom exhibit the same feelings. They feel trapped by societal pressures or more personal issues at home. This transforms school into a place of useless work if there is not a concrete future goal, which makes it very hard to want to stick around in the later years. Hopefully, seeing the boys in the movie overcome every obstacle in the way of realizing their dreams will help motivate the students at Western to equate hard work and study with due success.

Another major initiative of the grant was to engage the students in authentic learning. This was accomplished in the design problem presented. The students definitely felt, for a couple of days, like they were rocket scientists. In surveys distributed a week after the project was over, students were using the words 'design' and 'modify' like they had been doing this work all of their lives. Some even suggested that we test different water levels in the bottles for next year which displays significant thought in terms of scientific experiments dealing with different types of variables.

2.2 Nicholas Harth

Nicholas Harth worked at Hughes Center High School[2] with Matthew Barber (graduate Fellow). He implemented lessons several lessons in two quarters in the academic year 2002-2003. The Sound and Light activity was related to his Electrical Engineering course work, and included a field trip to a UC ECECS Dept. lab with 5 experiment and/or demonstration stations. The Viva Las Vegas project spanned over two weeks of class time and was very successful. The entire lesson plan, grading rubrics, photos, and examples of student work have been published[3].

The Viva Las Vegas Energy Project was developed for ninth grade physical science classes. The lesson was designed to be similar to the textbook's chapter culmination activity on power plants, which required students to analyze the different types of electrical generation occurring in their own community. Because over 99% of the power consumed in Cincinnati is generated using coal-burning technology, the Fellows selected Las Vegas, NV to study instead. Las Vegas draws power from a wide diversity of sources (coal, natural gas, hydroelectric, nuclear, geothermal, biofuel, wind, oil, and solar energy technology). The objective of the project was for the students to demonstrate their ability to evaluate the effects of a technology on a community, to summarize several processes by which electrical energy is obtained, and to present their researched evaluations in the form of a formal written report and as a poster presentation. Each student team represented a marketing team attempting to convince a Las Vegas City Council, made up of teachers and faculty from UC, to build a particular type of power plant in the Las Vegas area. Each group was assigned one of six power plant designs (solar, nuclear, geothermal, wind, fossil fuel or hydroelectric) to research. Each paper had to include a total of five rebuttals, one for every other kind of power plant, designed to force a group to learn about other kinds of power plant technologies besides their assigned one.

The students were excited and motivated by the project's multimedia kickoff presentation prepared by Nicholas. It included video and music clips featuring Las Vegas scenes. The students were asked to name ways that they saw energy being consumed in the presentation; the students were eager to participate and offered numerous interesting observations. The student presentations were conducted in a professional manner and with great enthusiasm.

2.3 Megan Perkey

Megan Perkey worked at Shroder Paidiea Academy[3]. Megan designed and implemented 5 lessons throughout three quarters during 2003-2004 in cooperation with Nicholas Harth (graduate Fellow). These lessons included the following hands-on activities:

1. *Functions:* the students designed roller coaster braking functions. The students collected data using toy cars on pre-designed tracks and analyzed the results using a spreadsheet program to create graphs and look at trends. Then they had to design and build a braking system that would stop a toy car the most effectively for the least cost.

2. *Logic and Reasoning*: the students played games requiring deductive reasoning in preparation for starting proofs in geometry; the goal was to show that thought processes involved in mathematical proofs are useful in decision-making and figuring out problems.

3. *Plate Tectonics:* the students designed and built buildings out of various materials and then saw the effects of a simulated earthquake on their buildings using special equipment from UC's Civil and Environmental Engineering Department called a Shake Table. The students directly experienced concepts of frequency, amplitude, acceleration, stiffness, resonance, natural frequency, and damping.

The documentation for the Plate Tectonics lesson is included in Section 4, with the exception of the actual handouts and answer keys.

3. Teaching as a Capstone Design Experience

Electrical and Computer Engineering seniors at the University of Cincinnati take a capstone design course sequence that extends across the entire senior year[4,5]. Students have a technical project advisor as well as a professor who supervises their senior project course work (Dr. Karen Davis served in both capacities for all three students described in the previous section.) The focus of this paper is how an alternate experience, Project STEP, can be accommodated in the framework of a capstone design course and used to satisfy ABET's professional component criterion. We address the portion of the professional component criterion that focuses on senior design in this paper:

Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political.[6]

In the traditional senior design project course, students complete assignments that include a project description, requirements specification, design drawings, technical specification and standards, task list and timeline, interface specifications, design review, test plan, status reports, and final presentation and demonstration. The STEP Fellows were required to complete these assignments along with additional assignments related to their specific STEP activities, such as an overview of state and national standards for math and science high school curricula. Examples from their assignments are given in the next two sections to illustrate how the ABET criterion for a capstone experience is satisfied.

3.1 Knowledge and Skills from Prior Program Experience

The College of Engineering at the University of Cincinnati has a mandatory co-operative education requirement that complements its required course work. Each student works a minimum of 4 quarters in industry corresponding to their engineering discipline. Nathan worked for 7 quarters at General Electric Aircraft Engines, Nicholas co-oped at Texas Instruments headquarters in Dallas for 4 quarters, and Megan worked at Ethicon Endo-Surgery for 6 quarters and Delphi Automotive Systems for 1 quarter. Their program experience includes both courses at UC and practical engineering experience in industry.

In the senior design course, students write a short essay that addresses how their co-op experiences and previous course work have prepared them to undertake their senior design project. It gives students the opportunity to reflect on the course work and co-op knowledge and skills that have brought them to the point where they are now ready to initiate and complete a significant design project. This addresses the ABET Criterion 4 mandate that the capstone experience should be the culmination of previously acquired knowledge and skills. Nearly all students mention that their course work and laboratories are valuable and contribute to their ability to reinforce and extend hands-on skills acquired during co-op. Some examples from Fellows' initial self-assessment essays include the following.

My course work has prepared me for the STEP program in several ways. First, I have developed a very keen understanding of many science and mathematics concepts, especially calculus and physics concepts, that are typically hard for high school students to grasp. Second, being an Electrical Engineer, I have had several experiences in course work with computer programming and modern technology, which are two skills that will prove helpful in completing this project. Lab classes have provided me with communication skills in technical settings. And finally, tutoring physics in the Engineering Fundamentals class Co-op

Physics has given me an understanding of working with students as an educator and provided helpful insight into their thinking processes, making it easy for me to accommodate learning guidance situations.

In several co-op jobs, I have been involved in the creation of information wizards and tools, which gives me much experience with creating user-friendly computer applications. Since General Electric Aircraft Engines is a largely technical company, I have also been exposed to many different computer programs and systems, and extensive modern technology in general. In my most recent assignments, I created three major website systems to perform nearly every function in GE's staffing center. These systems are being leveraged all over the country. All of these skills will prove helpful in the STEP program. (N. Dees)

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Project STEP is not only about building the math and science skills of K-12 students, but also teaching students to apply those skills through engineering practices. My co-op experience at Ethicon Endo-Surgery showed me how such skills are applied in industry. While at work, I was given the opportunity to make presentations. This helped me to gain confidence when speaking in front of groups and effectively communicate ideas to others. I also picked up many of the abilities associated with project planning, specifically organizational skills and time management. During my last quarter at Ethicon, I spent a lot of time trying to identify a new tissue model for a particular procedure. In doing this, I learned a lot about experiment design and innovation. I will certainly be able to apply such techniques as I plan unique lessons for classroom application.

The curriculum I have studied over the past four years has provided me with a solid technical background in the field of Electrical Engineering. Through my course work, I have also acquired a basic understanding of skills that are more readily applied in the other disciplines. This is particularly relevant for my project because STEP is geared toward Civil and Environmental Engineering. Having such depth within my own skill set makes it much easier to relate lower level topics to K-12 students. School has exposed me to technology in many forms. I have learned that it can be a great educational supplement, and I would like to pass that knowledge along whenever possible. I believe that by simply being a student myself I am making a connection with the students at Shroder. I understand the frustration associated with difficult concepts and the challenge of completing lengthy assignments. I hope to relate to these students on this common ground. (M. Perkey)

At the end of the spring term, all senior design students write a final assessment describing important lessons learned as a result of undertaking their project. Excerpts from one final assessment essay are given below as an illustrative example.

Participating in Project STEP as an undergraduate fellow has taught me a lot in the past year. I was immediately forced to remember the necessary organization and structure that is associated with junior high and high school. I learned to relate to students although we are at different stages in our lives and come from very different backgrounds. Still, we are united by the fact that we are all students. We were all there to learn.

Having spent the past five years of my life focusing my education on the specific area of Electrical Engineering, I found many new opportunities in this program to expand my horizons. Throughout the year, I took several education courses (Instructional Management, Field Practicum, and Instructional Planning). In doing so, I met people with career paths that were entirely different from my own. Still, they taught me about the very deliberate actions that teachers can take to be effective.

I also found that I was expected to teach material that I had not seen myself in several years. I did quite a bit of research in areas such as plate tectonics and chemical bonding. While learning these things myself, I discovered a new appreciation for the entire process which influenced my planning strategies greatly. Throughout the year, I learned about how the engineering process can be applied in many different ways. I was able to gather data from students, analyze that data, draw conclusions, and alter my designs to better suit my purposes.

On a personal level, I feel that I have improved my presentation skills and have become a more effective communicator. This will certainly help me in many other endeavors throughout my life. In short, I have experienced another level of professional growth. It is one thing to learn material and quite another to teach it. Working with these students and trying to help them see the connection between what they are learning in class and the field of engineering has helped me to realize it myself. (M. Perkey)

3.2 Realistic Constraints in Design

Teaching is not an obvious engineering design activity. However, bringing engineering and technology applications into inner city high school math and science classrooms requires creativity, planning, and engineering expertise. The Fellows have to design each lesson or activity, perform background research, develop a bill of materials, assemble and/or construct equipment, conduct experiments, collect and analyze data, and practice written and oral communication skills in order to deliver lessons. There are many constraints on these activities including curriculum needs and deadlines as well as state and national standards that have to be satisfied.

An outline of the documentation required by STEP for each lesson or module is given below.

- delivery date
- delivery location
- target STEM classroom
- grade level
- multimedia used
- background info
- research
- relationship to standards
- relationship to engineering
- brief summary
- formal write-up
- handouts with answer keys
- student work
- pre-assessment
- post-assessment
- student feedback and quotes
- teacher feedback and quotes
- module checklist
- reflection

Senior design students write an essay in the fall quarter describing three of the most relevant constraints and discussing how they impact the project's design. The Fellows chose economic, social, political, environmental and sustainability as having the most impact on their project as STEP participants. Some excerpts are included below.

> *The economic constraints concerning my project are minimal. There will certainly be expenses associated with the materials used in various learning activities and demonstrations; however, each school in the program is given a sufficient budget to work with over the course of the year, so there should be no out of pocket expenses. STEP Fellows also receive economic support in the form of a stipend to defer personal expenses while participating in the program.*
>
> *The social aspect of Project STEP is seen as one of its greatest advantages. As a Fellow, I will be working to develop new learning tools for K-12 students in the subjects of math and science. I am working with both students and teachers from several grade levels and subject areas who have an interest in the program and desire to be a part of it. It is wonderful to have such a wide range of pilot users to critique the product and help to improve it for future use. This project could certainly be considered a public service. After all, it is designed with long term goals in mind. We are trying to provide tools for teachers to work with to support the curriculum of Cincinnati schools.*
>
> *In the political sense, there are a few constraints, as well. The government sets standards for public education by mandating what subjects should be learned in certain grades, and to what extent. These standards are clearly reflected in the*

lesson plans of the teachers we are working with and should, therefore, be reflected in ours, as well. While finding ways to relate classroom concepts to engineering, we have to also make sure that they fit within the standards that have been issued for that grade level. Recent emphasis on standardized testing also relates to these standards as a political constraint. It is important that as we are developing our own lessons and activities, we keep those test concepts in mind. They should be incorporated wherever possible. These factors also contribute to a time constraint. Our project is designed to supplement current curriculum. Therefore, we need to be mindful about the amount of time that we are using in each classroom, so as not to compromise the goals of the primary instructor. (M. Perkey)

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Sustainability: The activity I will be creating for the STEP program will definitely have a life beyond my senior year. The activities will be created to accommodate a newly revised set of academic standards, and therefore could be used as classroom tools for years to come. All lesson plans will also be posted on College Livetext, a tool that allows work to be shared all over the country and easily accessed and printed and leveraged by other teachers. The lesson plan for my activity will also be broken down into a series of events so that a teacher could even pick and choose what they want to incorporate into their own classrooms. The grading scheme might not be sustainable as each teacher has their own style of grading, especially since different high school classrooms can have such different natures. To combat this, I will try to design my assessment to be very general and unbiased.

Social: Students and teachers of all backgrounds and ages will use the activity I create in possibly a multitude of schools in the Ohio school system and beyond. Therefore, the content of the material I am trying to present must be politically correct and appeal to all possible users. I will account for this in many ways. The materials will be very generic to appeal to all genders. The examples I use as analogies for learning will have to involve objects that most everyone would be familiar with. This will ensure that a user will be able to form a personal relation with the application or lesson. (N. Dees)

4. An Example Lesson: Plate Tectonics

This section gives the documentation included with M. Perkey's senior design report for an example lesson on Plate Tectonics taught by M. Perkey and N. Harth.

Authors: Megan Perkey and Nick Harth
Delivery Date: April 19–23, 2004
Delivery Location: Shroder Paidiea Academy Classroom
Target STEM Classroom: Science
Grade Level: 7

Multimedia Used: Laptop computer, data projector, shake table, TV/VCR

Background Info:

This lesson occurred as part of a unit in plate tectonics; however, it was primarily directed towards the destructive effects and prevention strategies associated with earthquakes. The previous unit that the students had covered in class dealt with the concept of waves; therefore, they were already familiar with terms such as "frequency" and "amplitude." This made it much easier introduce concepts such as natural frequency, resonance, and damping.

Research (online links, etc.):

- USGS Earthquake Hazards Program – Northern California – http://quake.wr.usgs.gov/info/1906
- Historical Earthquake – 1985 Mexico City – http://www.garfield.k12.ut.us/schools/ehs/msse/quakes/85mexqua.htm
- Earthquake Damage, Mexico City, September 19, 1985 – http://www.johnmartin.com/earthquakes/eqshow/647003_00.htm
- MCEER (Multidisciplinary Center for Earthquake Engineering Research) – Designing Structures to Perform Well During an Earthquake – http://mceer.buffalo.edu/education/exercises/struct.asp

Relationship to Engineering:

These students had spent the previous week studying the science of plate tectonics. They have learned about the causes of earthquakes, and this lesson is designed to help them consider the effects. Civil engineers design buildings with an understanding that there is always a risk of an earthquake. In certain parts of the world, that risk is greater than others, but still, precautions are always taken during the design process. In order to better understand the logic behind this engineering design process, the students must first realize how and why earthquakes are so destructive (natural frequency and resonance); they can then learn how other scientific concepts (damping and conservation of energy) can be used to counter act those effects.

Brief Summary:

Throughout the first part of this lesson, the students are introduced to the concepts of frequency, amplitude, acceleration, stiffness, resonance, natural frequency, and damping. They then participate in several exploratory activities that illustrate those concepts in a hands-on atmosphere. The second part of the lesson is a one hour movie about one particularly destructive earthquake that took place in northern California. This is meant to illustrate the reality of the situation to students. In part three, they are taught about the effects that earthquakes have on buildings by simulating the event on a shake table. They also discuss some of the basic design techniques that civil engineers use to help them to sustain such forces. The students then have the opportunity to build their own structures (from a variety of materials) and test them out on the shake table.

Vocabulary Terms:
frequency (review), amplitude (review), acceleration (review), stiffness, resonance, natural frequency, damping

Standards: *Ohio Benchmarks for Grades 6-8*
EARTH and SPACE SCIENCES

- Describe the processes that contribute to the continuous changing of the Earth's surface (e.g., earthquakes, volcanic eruptions, erosion, mounting building).
- Describe the interior structure of Earth and Earth's crust as divided into tectonic plates riding on top of slow moving currents of magma in the mantle.
- Explain that most major geological events result from plate motion.
- Describe how landforms are created through a combination of destructive (erosion and weather) and constructive (volcanic eruptions, depositions of sediment) processes.
- Illustrate how the three primary types of plate boundaries cause different landforms.

SCIENCE and TECHNOLOGY

- Give examples of how technological advances, influenced by scientific knowledge, affect the quality of life.
- Design a solution of product taking into account needs and constraints (cost, time, tradeoffs, etc.)

PHYSICAL SCIENCES

- Demonstrate that waves transfer energy.
- Demonstrate that vibrations in materials may produce waves that spread away from the source in all directions (e.g., earthquakes).

Objectives:

1. Student will be able to define the above vocabulary words and have a general understanding of the scientific concepts.
2. Student will be able to describe an earthquake in terms of frequencies.
3. Student will be able to identify the natural frequency of an object.
4. Student will understand what determines the natural frequency of an object.
5. Student will be able to explain how and why earthquakes are destructive.
6. Student will be able to contribute ideas to the design of a building that is meant to withstand an earthquake.
7. Student will have some knowledge of specific historical earthquakes.

Materials Required:
Guitar, rubber bands, model buildings of different height and weight, shake table, building materials (e.g., styrofoam, cardboard, Legos, play-dough, felt, pipe cleaners, masking tape, duct tape, rubber cement, foam, dowel rods, bubble wrap, construction paper, film canisters), movie

Activities:
Day 1: Review the concepts of frequency, acceleration, and amplitude. Use the guitar and rubber bands to explain the new concepts of stiffness, resonance, natural frequency, and damping. Use wood/block tennis ball for students to practice finding the natural frequency of an object.

Day 2: Show earthquake movie.

Day 3: Give shake table demonstrations with various "buildings." Students will review concepts from day one, and use the shake table to model earthquakes and identify the most dangerous situations for the various buildings. Students will use construction materials in groups to construct their own buildings, designed to stand up to an earthquake.

Day 4: Students will have the opportunity to try their own buildings in a shake table earthquake.

Assessment of student learning:
Day 1: The students will be asked to fill out a worksheet during the lecture period in which the new vocabulary words are defined. They will also be asked to provide a written response to various questions as they move through the learning activities.

Day 2: The students will have a worksheet that they will use to follow along with the video to ensure that they are paying attention.

Day 3: The students work though questions on a worksheet as they participate in a class discussion. Everyone will answer the questions together as we move through the material. In groups, the students will be given time to design and build a structure that they believe will endure a simulated earthquake on the shake table.

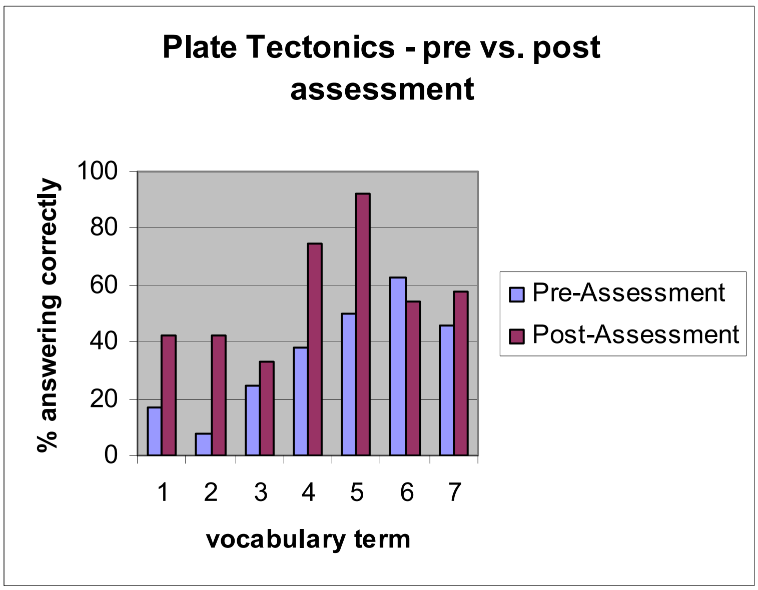
Assessment of the activity:
1) Students will complete a survey at the end of the 4 day to evaluate their own learning and overall enjoyment of the lesson.

2) Classroom teacher will complete a follow assessment as well for feedback, future knowledge, and assessment data.

Assessment Results:

The table below shows the percentage of students who correctly matched the term with its definition on a multiple choice quiz before and after the lesson.

		Pre-Assessment	Post-Assessment
1	frequency	17%	42%
2	resonance	8%	42%
3	amplitude	25%	33%
4	acceleration	38%	75%
5	stiffness	50%	92%
6	damping	63%	54%
7	natural frequency	46%	58%



Student Feedback:

	Very interested	**Somewhat Interested**	**Not Sure**	**No Interest at all**
How would you rate your interest in the field of engineering?	41%	35%	18%	6%

	Increased my Interest	**Decreased my Interest**	**Did not affect my Interest**
Did this program affect your interest in engineering in any way?	71%	5%	18%

	a lot	a little	nothing new
How would you rate your level of learning today?	86%	14%	0%

	Definitely	Sort of	Not Sure	No
Did this program make you feel more confident about your ability to learn math and science?	48%	24%	28%	0%

What did you like most about these activities?

- I liked when we build the buildings to see if they would last in an earthquake.
- I liked when we did the hands-on activity with the shake table.
- Building my own building.
- There were exciting and fun activities for kids.
- It was very fun, and I learned a lot.

What did you like the least about these activities?

- I didn't like when we put the building on the shaker.
- When we found out what we had to build out of.
- I did not like the written part.
- It was kind of boring when we had to write.
- When our structure fell.

Reflections:

Day one seemed to effectively communicate the necessary concepts, and the students were even able to use them correctly later in the week without being coaxed. We tried to design the entire lesson on a conceptual basis because we felt that involving math may be too difficult for seventh graders. This lesson could, however, be easily adapted to a higher level science class. In that setting, math could easily be incorporated to create a more challenging experience for the students.

Having students design and build their own structures really added to engineering experience. They were extremely intrigued by the shake table and seemed to enjoy using it during the simulation process. We did drastically underestimate the amount of materials that 120 students (working in groups) would use to create their buildings, but after restocking, things seemed to run smoothly. They were also asked to explain to the class why they designed their building the way that they did before testing it on the shake table. A few extra specifications were stated after the students started their designs. Their buildings had to be more than 20cm tall and no more than 12.5 cm wide (in order to fit on the shake table).

In the end, this lesson seemed to be a great extension to Mr. Voll's plate tectonics unit. The material even made up a good portion of the student's midterm exam.

5. Reflections on Classroom Experiences

The Fellows provided informal reflections related to their classroom experiences. These excerpts provide additional insight into the unique professional growth afforded by participating in Project STEP as a capstone design experience.

> *Spring quarter went great overall I believe. I spent much more time in the classroom and went over the hours required by STEP by 10-20 hours. I got to know the students more individually and understand some of the concepts we were learning about in STEP (such as learning habits and personality types) and apply them to the students I was working with.*
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> *The culmination of the year of work came during the 2.5 week period where the kids were ours and we led the class in every way during that time frame. This came during our delivery of the module we developed entitled Viva Las Vegas. It was a real life application and the kids were doing real work that people working on trying to get funding for a new type of power plant would go through. It required some knowledge, research and critical thinking in the way of taking in information and making some personal judgments from the material provided. Authentic learning? You betcha!* (N. Harth)

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> *A typical senior design project involves developing or inventing an idea and undertaking the challenge of actually creating it. There is a struggle and a series of complications and the learning comes from working through these issues. The main struggle of a STEP Fellow is the coordination of minds. There are numerous customers that must be pleased in the senior advisor, the program coordinators, the high school teachers, and the seventy students. At the same time a new profession is explored – teaching. Walking into a foreign classroom in an inner city school for the first time with pressure to represent some form of technical expert from the local college can be very intimidating. The first lesson I learned is that being a schoolteacher is HARD.*
>
> *The grant's initiative to relate to students' real lives extended my own experience as well. The school I attended until the eleventh grade was a small parochial/catholic high school with only 50 people in each class and a rather expensive tuition. I finished the twelth grade at Loveland High School, a brand new facility in a very quaint suburb with a slightly above-middle-class population. And neither one were diverse in any sense of the word. Western was the opposite. There were diverse people, diverse motivation levels, diverse behaviors, diverse intellects, diverse backgrounds, and diverse attitudes. What an incredible challenge to bring a lesson to the group and have everyone be interested and learn. See what I mean by HARD!?*

One of the most interesting dynamics to me was the way students interacted with each other in this school. Every day, students spoke to each other in confrontational tones, but after a series of offensive exchanges, smiles emerged. It was all a game, a display of pretend power, preparation for the real world when their image and honor would be threatened. They practiced amongst each other and sometimes with the teachers every day. But I always felt that behind it was a sense of respect and brother/sisterhood. Even when dealing with me, when I would ask students to do something, they would challenge me at first, and if I ignored the challenge, they would carry on as I had asked them to do.

This project was not just a nine-month insight into the future of an Electrical Engineer and his or her field. It was a nine-month insight into the future of every person in every field of society. Although I will not end up with a patent opportunity, it has been a great discovery to again learn where real opinions and intelligence begins. These students and others like them are the near future of our country. I hope they will be motivated to take on that task. (N. Dees)

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In terms of student assessment, we were able to gather quite a bit of data. The grades for most activities were generally high; however, we found that students did perform quite poorly on the second part of the Chemical Bonding lesson. The grades were adjusted appropriately, and we attributed the poor performance primarily to the fact that there was quite a bit of work to be done in a short amount of time. Consequently, the students were forced to attempt the unfamiliar work at home where little outside help was available. This did, however, alert us to the fact that not all students had been able to fully comprehend the lab. In response to these findings, we addressed the same material during another class period, using the lab as a reference. This helped to reinforce the concepts that we had hoped to communicate, and the students were given another opportunity to demonstrate their knowledge on their next exam in the form of an essay question relating to the lab.

We never received overwhelmingly negative feedback from the students in regard to our lessons. In fact, for the most part, they were quite positive. We always encouraged the students to be completely honest when evaluating the activities and explained that the forms were anonymous and would not affect their grades in any way. There were some students who were much more interested in the concepts and ideas related to engineering, but those who were not so inclined still actively participated.

Each lesson had particular strengths, and I certainly recognize room for improvement and even expansion in each of the activities. Certain things have been used successfully by other teachers during the year. This tells me that there is certainly educational value in the materials that we have created.

I was introduced to reflective teaching early on in the year, and I have found it to be an extremely useful tool for self improvement. My journal served as way for me to remember what should be repeated, and what should be omitted from my teaching style as well as the lessons themselves. I was able to take this form of evaluation even a step further by having my teaching observed and reviewed by an experienced teacher. She provided extremely useful feedback, and I was able to to advantage of her suggestions. (M. Perkey)

6. Meeting STEP Objectives

The modules created by M. Perkey and N. Harth are the basis for the following discussion. M. Perkey describes how each objective of her senior project, derived from Project STEP objectives, was met by their activities at Shroder Paideia Academy.

- *Develop hands-on, inquiry based lessons and educational practices to supplement current math and science curriculum.*

  We were able to create five primary modules throughout the year in the areas of mathematical functions, logic and reasoning, chemical bonding, basic physics, and plate tectonics. All of these modules contained hands-on activities and required students to seek answers to engineering related questions. In each case, our lesson plans served as enrichment to the instructor's pre-determined curriculum.

- *Operate within the state and national academic standards.*

  Relevant mathematics/science and technology standards for grades eleven, ten, and seven that are addressed during each lesson are included with the lesson's documentation.

- *Incorporate technology whenever possible at the same level of education.*

  We were able to bring technology into the classroom on several occasions during the year. During our functions project, we asked the students to perform data analysis in Microsoft Excel on laptop computers. During the chemical bonding unit, the students were able to gain experience using digital multi-meters to measure the resistivity of a variety of substances, and the plate tectonics unit allowed us to bring a shake table into the classroom, on loan from the UC Civil Engineering department.

- *Provide opportunities for students to learn about engineering as a profession.*

  After every lesson that we gave, we talked with the students about how the particular activity that they had just finished related to careers in the field of engineering. We also had opportunities to talk with students both as a group and individually about our personal experiences in the field.

- *Provide activities and lesson plans that are designed for long-term use by a variety of instructors.*

  The activities that we created are organized and are currently available to other STEP fellows. One of our modules (chemical bonding) has already been used by another teacher. Whenever possible, we attempted to provide expansion opportunities as part of our lesson plans to make the lessons more adaptable for a variety of audiences.

The Fellows have all completed their B.S. degrees in Electrical Engineering. Nathan Dees has continued at UC with graduate studies in Physics. He intends to research medical imaging in conjunction with the physics department and UC's medical school. Nicholas Harth is currently an NSF STEP graduate Fellow and Electrical Engineering Master's student researching in the area of organic light emitting diodes. Megan Perkey earned her B.S. in Electrical Engineering in 2004 and works for a marketing research firm that performs analysis to provide pre-market insight for consumer package goods to firms such as Proctor and Gamble.

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Biographies

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