

AC 2010-95: BEST PRACTICES PANEL 2010

Stacy Klein-Gardner, Vanderbilt University

Stacy Klein-Gardner is the Associate Dean for Outreach at the Vanderbilt University School of Engineering. A former high school teacher and active K-12 engineering curriculum developer, Dr. Klein-Gardner leads the Best Practices Panel committee's work for the K12 Division.

Marlene Aviles, Dr. Ercel Webb School # 22, Jersey City School District

Marlene Aviles is an elementary school teacher at the Dr. Ercel Webb School #22.

Augusto Macalalag , Stevens Institute of Technology

Augusto Z. Macalalag, Jr., is a professor at Stevens Institute of Technology.

Jennifer Case, East Middle School

Jennifer Case is a middle school teacher at East Middle School.

John Brockway, East Middle School

John Brockway is a middle school teacher at East Middle School.

Christie O'Hara, Colorado School of Mines

Christie O'Hara is a graduate student at the Colorado School of Mines.

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Michael Asheim is a graduate student at the Colorado School of Mines.

Barbara Moskal, Colorado School of Mines

Barbara Moskal is a professor at the Colorado School of Mines.

Brian Lien, Princeton High School

Brian Lien is a high school teacher at Princeton High School in Cincinnati, OH.

Eugene Rutz, University of Cincinnati

Eugene Rutz is a professor at the University of Cincinnati.

Best Practices Panel Winners **ASEE K-12 Engineering and Pre-College Outreach Division**

The **K-12 ENGINEERING AND PRE-COLLEGE OUTREACH DIVISION** of ASEE is recognizing exemplary K-12 – university partnerships in engineering education at the 2010 ASEE Annual Conference and Exposition in Louisville, KY. To do this, the Division is sponsoring a panel session on Best Practices in K-12 and university partnerships. Submissions chosen for participation in this session demonstrate a true partnership between a K-12 school (or schools) and an engineering school/college at a university.

Selected partnerships have *proven success in the classroom* and demonstrate *engineering engagement and knowledge acquisition* by K-12 students through age appropriate activities and lessons. Best Practices Partnership Panel winners' papers are authored collaboratively between engineering and technology education faculty and K-12 teachers. Details on *the partnership's structure and goals* and *the successful strategies employed to overcome challenges and obstacles* are included. Each partnership's description includes sample student product(s) and conveys how other partnerships may emulate the project.

One proposal winner was chosen by a panel of reviewers at each of the following levels: preschool or elementary school; middle school; high school. The three winning abstracts have been used to create a conference paper for this session.

PRE-SCHOOL / ELEMENTARY SCHOOL WINNER

Promoting 21st Century Skills Through Science and Engineering Education

Marlene Aviles, Dr. Ercel Webb School #22, Jersey City, N.J.

Augusto Z. Macalalag Jr., Stevens Institute of Technology, Hoboken, N.J.

Program Overview & Partnership Structure

In today's changing global economy, science and technological literacy are crucial for students to compete in the 21st century¹. The widening gap in achievement and low interest in science, engineering, and mathematics between students in the U.S. and those in other developed countries are major concerns. Moreover, a good number of students in the U.S. are being taught by teachers who are lacking the qualifications, content knowledge, and pedagogy to teach science, engineering, and mathematics².

To address these challenges, the Partnership to Improve Student Achievement (PISA) program provided 47 grade 3-5 teachers in N.J. with high quality science and engineering curricula, classroom-focused professional development, and mentoring designed to address topics in key content areas in science and engineering education. Scientific inquiry and the engineering design process were the two vehicles used in the instructional activities to promote teachers' content and pedagogical knowledge and increase students' achievement and engagement in science. The partnership included six urban districts in northern N.J., a science center, teacher education institution, and an engineering college. Teachers received 124 hours of continuous professional development including a two week summer institute, one hour monthly classroom support visits (coaching, modeling, curriculum alignment, and planning), and three professional development days during the school year. The project is now in its third year.

The partnership goals are to (1) increase teachers' content knowledge in specific science topics and engineering, (2) improve the teachers' notions of scientific inquiry, (3) increase participating teachers' preparedness in creating, adapting, and delivering inquiry-based science and engineering lessons, and (4) increase students' content knowledge in specific science topics and engineering.

Program Content

Each year of the PISA program has focused on a different science discipline with corresponding technology and engineering lessons. Elementary teachers who participate in all three years of the program are exposed to higher level content knowledge in each of these science disciplines. The first year was devoted to life and environmental sciences, earth and space sciences in the second year, and physical sciences is the focus of the third year. During the two-week summer institute held in 2009,

teachers learned physical science content of forces, motion, and electricity through lectures, hands-on activities, field trips, Internet based projects, collaborative work, reflections, model-based inquiry, and the engineering design process administered by the faculty and staff of the engineering and teacher-education colleges. Teachers engaged in two *Engineering is Elementary (EiE)* modules over focused on the engineering design process.

Proven Success in the Classroom

Based on our pre- and post- tests administered to teachers and students in treatment and comparison groups in year 1, participating teachers showed science and engineering gains of almost *3 times greater* than teachers in the comparison group. Students of teachers in the treatment group had gains in science and engineering more than *2.5 times greater* than students in the comparison group³. In year 2, both teachers and students in the treatment group *significantly improved their scores in engineering questions* compared to the comparison group⁴. Moreover, teachers' *improved their notions of scientific inquiry* after 2 weeks of intensive professional development workshops⁵.

A survey was given in the beginning of the 2009 summer workshop to treatment teachers in year 2 to identify the activities that worked well in their classrooms, indicate the science and engineering activities that they will most likely implement again, and challenges that they encountered in teaching the lessons (Note: challenges encountered by teachers will be discussed in a separate section below). Overall, half of the 34 teachers who responded to the survey implemented ten or more of the 27 activities that they learned during the summer 2008 workshop. Twenty-five percent did 15 or more activities. All but one of the activities introduced in the workshops was used by over half of the teachers. These were two model-based inquiry lessons (phases of the Moon and Earth's seasons) and two engineering lessons (designing walls and creating windmills). Almost all of the teachers who had used an activity reported successful implementation. Moreover, almost all of the teachers who used an activity reported that they would use it again next year. Finally, almost all teachers felt that the PISA activities had helped them meet their goals of having more engaging activities, having more activities that bring science to life and connect with the real world, and having activities that include problem-solving and experimentation. The survey also asked the teachers to what extent the PISA activities had helped them meet their goals. They said that PISA activities *engage and excite their students (97%), bring science to life for students (97%), connect with the real world (94%), promote problem solving and experimentation (94%), improve students in science (94%), and appeal to diverse group of students (91%)*.

In this section, I will highlight the successes in the classroom of Marlene Aviles. Marlene teaches fourth grade students in an urban school in N.J.. She is a model teacher whose work exemplifies how a classroom teacher can successfully integrate engineering activities into the existing curriculum. In the first year of program, she implemented the following EiE modules: *Water, Water, Everywhere* (Environmental Engineering), *Best of Bugs* (Agricultural Engineering), and *Just Passing Through* (Bioengineering). In year two, she implemented: *Catching the Wind* (Mechanical Engineering) along with the engineering projects implemented the previous year.

Marlene uses the *EiE* materials in conjunction with related science topics and has found that the *EiE* lessons further her objectives for science in the classroom and reinforce concepts taught in class. For example, upon completing a science unit on the human body last fall, she implemented “Just Passing Through: Bioengineering” in which the students design and construct a model membrane. Her students feel comfortable using the engineering design process and it is obvious to the observer that her students were engaged and excited; they have learned that there are different ways to solve problems. They have also learned that if a solution does not solve the problem, to continue looking for a solution that will work. Marlene reports that her students’ understanding of and positive attitude toward science has improved as a result of interaction with the *EiE* materials. See attached planning sheets and photographs.

On top of these pre-developed projects, she developed her own engineering lessons. During a unit on *Inventors of Tomorrow*, Marlene implemented an invention project in which the students were required to use the Engineering Design Process to design and invent an object that would help humanity. The students were required to identify a problem that students face and imagine different possibilities to solve the problem. The student then illustrated the design they chose and created a model to display to the class. For instance, one group decided to create a small briefcase that would hold all the essentials needed for their everyday life (e.g. pens, notebooks). After asking the question of what was needed the students imagined different ideas they could use. They drew a picture of the case and labeled each part. They created a prototype of what the final product would look like with an explanation of its parts and functions.

Strategies Employed to Overcome Challenges and Obstacles

The survey asked the teachers to describe the challenges that they encountered in implementing the science and engineering projects. Analysis of their answers revealed five major categories of teacher concerns: (1) diverse student population, (2) time and test preparation issues, (3) resources, and (4) limited science curriculum. Teachers mentioned that students who are at different levels academically and behaviorally were their major concern. Specifically, they had problems implementing some of the PISA activities because students have different academic abilities, behavioral/discipline problems, not used to science inquiry and engineering design process, and lack of collaborative working skills. To address these concerns, the program instructors helped teachers individually, through the regular monthly classroom visits, to modify or differentiate their instruction and the different PISA activities for their students. In terms of time and test preparation issues, teachers mentioned that school time has been always devoted to subjects that are tested, which are math and language arts. They also mentioned that daily instructional time for science is limited to 30-40 minutes, which is not enough for big science and engineering projects. To address this concern, we worked with district administrators and teachers to allocate more time for science and give teachers time and support to implement the projects. Third, several teachers mentioned the lack of resources and materials in their classrooms to implement the activities in the project. Most resources for science are outdated and limited. Moreover,

they mentioned the lack of space and scheduling issues to use a classroom, computer laboratory, or science laboratory. To address these needs, the instructors brought the materials with them to the classroom to help the teachers. This encouraged teachers to share materials with other teachers and with other schools. As for the space issue, we worked with school administrators to provide time and space for teachers. Teachers mentioned the limited science curriculum in their districts. We worked with our district partners to address these challenges. We are proud that one of our districts recently revised their science curriculum that incorporated science and engineering.

The critical elements of success are committed partner schools and strong relationships with the school administrators and teachers. To ensure that teachers implement the content and skills learned during the professional development and remained motivated and excited about their participation in the program, monthly classroom visits and mentoring via the program listserv as well as email and phone calls have proven invaluable. Recommended strategies for classroom visits are a combination of co-teaching, modeling, and observation/feedback.

Sample Student Products Attached

- Just Passing Through: Exploring Membranes
- Just Passing Through: Designing Model Membranes PLAN
- Just Passing Through: Designing Model Membranes CREATE
- Student Photos
 - Lesson One: Designing Model Membranes
 - Lesson Two: Inventors of Tomorrow

Just Passing Through: Exploring Membranes


Name: _____

Date: 305

A

B

Exploring Membranes: Raisin Skin

	How long was the raisin in water?	Do you see holes in the raisin membrane?	What does the raisin look like? What are some of the raisin's properties?
Raisin "1"	It was never in water.	NO NO	Soft, wrinkle, little bit, Juice
Raisin "2"	5 hours	No.	moist, very soft, lots of Juice
Raisin "3"	48 hours	No.	Very moist, wrinkles, no Juice
Raisin "4"	2 days	NO	big, squishy, lots of water

EIE: Designing Model Membranes
 © Museum of Science, Boston
 Duplication Permitted

3-1

Lesson 3: Exploring Membranes

Just Passing Through: Designing Model Membranes PLAN

Name: _____ Date: _____

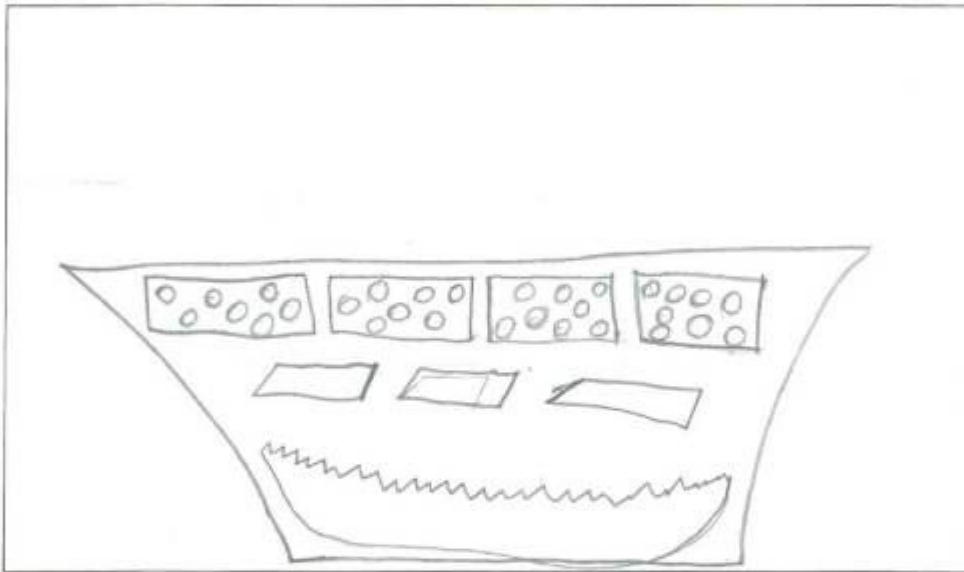
A

Design #

**Designing a Model Membrane
Engineering Design Process:
Plan!**



Directions: In the space below draw a diagram of your model membrane design. Label the parts.



1. List the materials that you will need:

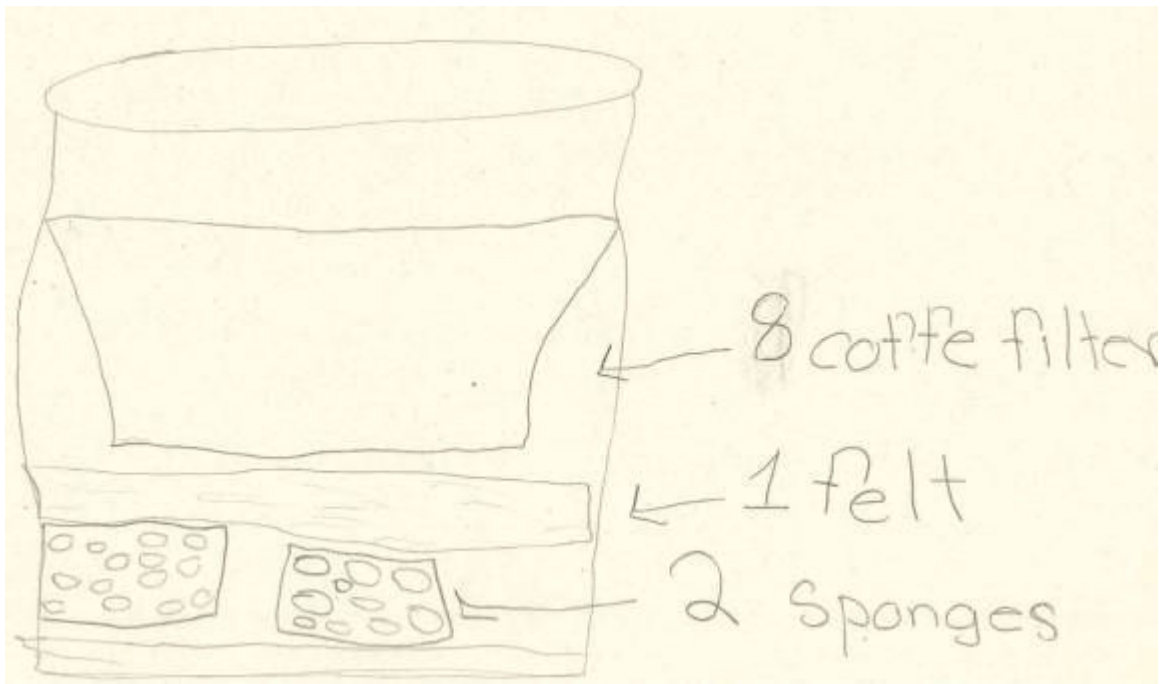
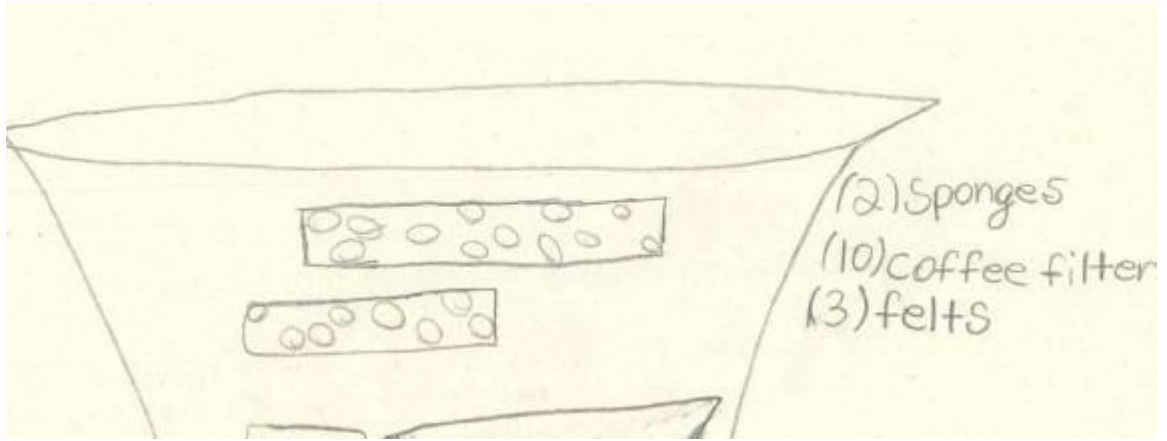
(4) Sponges _____ (3) felts _____

(6) coffee filters _____

2. Do you think that water will pass through your model membrane? Why or why not?

I think some will because they all absorb water.

Just Passing Through: Designing Model Membranes PLAN

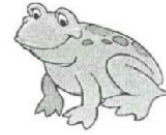


Just Passing Through: Designing Model Membranes CREATE

Name: _____ Date: _____

Design #

**Designing a Model Membrane
Engineering Design Process:
Create!**



Directions: Observe your model membrane design to answer the questions below.

1. After 24 hours, how much water collected in the liquid measuring cup? Circle your answer:

Too much

Too little

Just enough

2. What part(s) of your model membrane design worked well? Why do you think so?

The sponges because they absorb more water and the fllets

3. What parts of your model membrane design did NOT work well? Why not?

The coffe fillters because water goes through fast

Name: _____ Date: _____

Design #

Designing a Model Membrane Engineering Design Process: Create!



Directions: Observe your model membrane design to answer the questions below.

1. After 24 hours, how much water collected in the liquid measuring cup? Circle your answer:

Too much

Too little

Just enough

2. What part(s) of your model membrane design worked well?
Why do you think so?

The sponges because they absorb more water and the fllets

3. What parts of your model membrane design did NOT work well? Why not?

The coffe fillters because water goes through fast

Student Photos

Lesson 1: Designing Model Membranes



After identifying the problem and imagining different ways to design their model membrane, students began to build.



These students used their plan to build their model membrane.



Students were preparing to test their prototype.

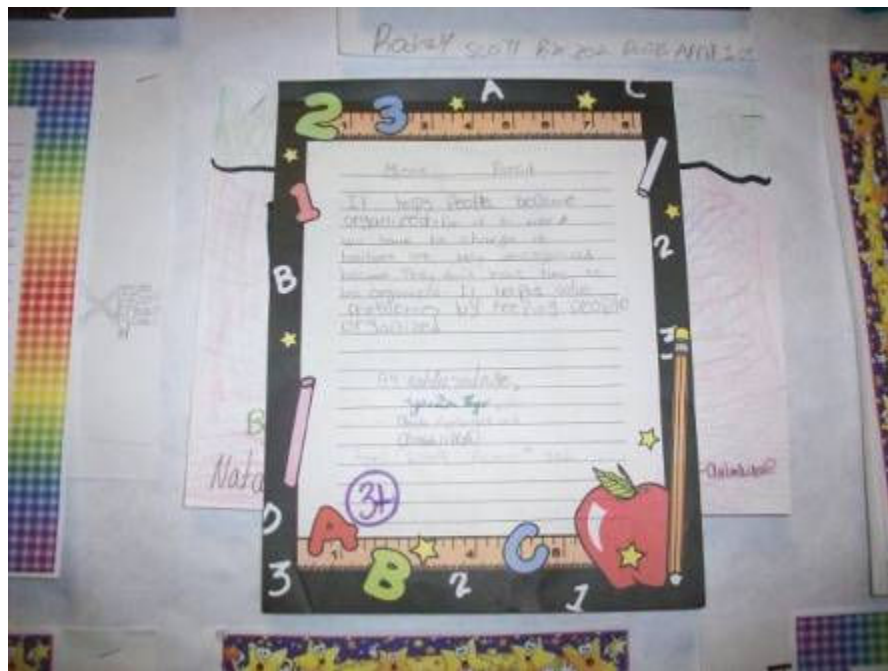


Student's testing their design.

Lesson 2: Inventors of Tomorrow



Invention Wall



Designing a Personal Organizer Write-Up



Diagram of the Organizer

MIDDLE SCHOOL WINNER

Energizing Middle School Mathematics and Science: An NSF GK-12 Initiative

Jennifer Case and John Brockway, East Middle School, Aurora, CO
Christie O'Hara, Michael Asheim, and Barbara Moskal, Colorado School of Mines, Golden, CO
Linda Lung, National Renewable Energy Laboratory

Partnership Structure: The Colorado School of Mines (CSM) and Aurora Public Schools (APS) has collaborated on the middle school partnership, *GK-12 Learning Partnerships: Creating Problem Centered, Interdisciplinary Learning Environments* (NSF, DGE-0638719) since 2007⁶. As part of this partnership, CSM graduate students in mathematics, science and engineering are placed in support of APS middle school teachers and their students for up to fifteen hours each week throughout the academic year. Twelve middle school mathematics and science teachers participate annually, impacting approximately 1200 students per year. Each participating teacher has the option of remaining in this partnership for up to two years, with a three year continued support immediately following. APS schools are largely Hispanic, presenting both language and cultural challenges. During the summer prior to classroom placement, CSM graduate students receive instruction on K-12 education, literacy in mathematics and science classrooms, cultural differences and effective strategies for working with diverse populations. Partnership teachers attend a ten day, six hour per day summer workshop, that is offered simultaneous to the graduate student summer session, and this workshop addresses the applications of mathematics and science to engineering. Joint sessions are held during the summer session among graduate students and teachers, allowing for collaboration and brainstorming on lesson plans that will be implemented during the academic year. The bond between the graduate students and the teachers begins to develop during the summer and is strengthened throughout the academic year. These workshops are taught in collaboration with expert district teachers, CSM faculty, and, since 2009, engineers and scientists from the National Renewable Energy Laboratory (NREL). Each workshop further offers the option of continuing education credits which are necessary for participating teachers to maintain state teaching certification.

Partnership Roles: The graduate student's role in the classroom is to share their excitement, knowledge and research of mathematics, science and engineering with the students and teachers in the classrooms. A common first report of graduate students are surprise that neither the teachers nor students immediately accept or understand their scientific explanations; nor do they accept or understand the graduate students' enthusiasm for the subject. This challenges the graduate students to reformulate, rephrase and re-explain. The role of the teacher is that of a mentor to the graduate student and as the instructional leader for the classes. Faculty, engineers and scientists act as consultants to both the graduate students and the teachers.

Benefits and Goals: The long term benefits of the developed skills to the graduate student are obvious: mathematics, science and engineering graduate students, the next generation of scientists and engineers, will be able to explain their subject area to the broader population as

well as to their own students. This is a skill which is rarely found in the professional engineering and scientific community. The benefits to the middle school students are also apparent: the participating students are exposed to successful, near-peer role models in mathematics, science and engineering. The participating teachers benefit from the acquisition of continuing education credits, advancement of their professional knowledge, availability of additional classroom resources and classroom support in the form of a graduate student. CSM faculty, and NREL engineers and scientists benefit from the availability of a well-designed outreach program to which they can connect their research efforts. The primary goal of this partnership is to increase the participating teachers' and students' knowledge and understanding of mathematics, science and engineering and how these subjects are applied in the world.

Even and Integrated: Each year, this partnership is adapted to the changing needs of the district and university. For example, in the summer of 2008, scientists and engineers who represented a variety of different fields, including computer science, environmental science, physics, mathematics, and engineering, provided instruction at the summer workshop. This design was based on the school district's request that the participating teachers be exposed to a broad range of fields. However, a common concern expressed by the participating teachers was that the workshop was "too much." The teachers requested that the next workshop have a contained focus. Energy and renewable energy were selected as the area of focus for the next workshop for the following reasons: i) energy and renewable energy are growing with respect to public concern and research, ii) sources of renewable energy, i.e., wind, water, and sun, are within the experience base of young children, iii) energy and renewable energy concepts are naturally linked with mathematics, science, and engineering, iv) through the newly funded *Renewable Energy Materials Research Science and Engineering Center* (NSF, DMR-0820518) there is a research team on CSM campus that has the appropriate expertise in these areas and a strong interest in collaborating with this program and v) these concepts are reflected in the state's science learning standards but not in the current curriculum⁷. NREL, due to its expertise in renewable energy as well as its close proximal location to CSM and APS, was also recruited to assist in this partnership. As this example illustrates, at the broadest level, this partnership's design and implementation is regularly adapted to meet the needs and requests of the partners. The next section provides a classroom example, illustrating the bond and collaboration that emerges through this partnership at the classroom level.

Classroom Example with Age Appropriate Activities: This section focuses on the classroom experiences of two middle school teachers, Mr. Brockway and Ms. Case, and their students, all of whom are participating in this partnership. The graduate student, Christie, is a second year master's student at CSM. Both teachers and the graduate students attended the summer workshop. Christie provides seven and half hours of direct classroom support to each teacher every week throughout the academic year (total of 15 hours per week). Since these teachers are in the same school, this group works as a collaborative team, sharing ideas across classrooms and maximizing the benefits of jointly created lesson plans. Both teachers reported that when they joined this partnership, they primarily taught mathematics in a traditional manner, lecture based

and textbook driven. This example illustrates a different approach to mathematics instruction, one which is experience based and engineering rich, and one that is based on the joint experiences and collaborations of the partnership.

Mr. Brockway and Ms. Case each teach an integrated and an advanced integrated mathematics class to sixth grade students. The unit described here is based on an adaption of a unit from the summer workshop and provides foundational knowledge necessary to electrical engineering (as well as other areas of engineering, such as chemical and mechanical engineering). During the workshop, NREL scientists and engineers provided each school with a classroom set of instructional devices and demonstration units. A “Kill-A-Watt”, a device used to measure the power (watts) of an electrical device uses while plugged into a standard wall outlet, was one of the tools. Terms used in electrical engineering, such as “current,” “voltage,” “power,” and “energy,” were defined conceptually and mathematically and illustrated using the Kill-A-Watt device. The teacher/graduate student teams used this device to measure the power consumed by different electrical devices. NREL engineers and scientists were available to respond to questions and provide support as the teacher/graduate student teams began the process of brainstorming how these units could be used in the classroom. Mr. Brockway, Ms. Case and Christie reflected on the summer instruction and the lesson plan during the academic year. Jointly, they decided to implement the Kill-A-Watt unit in their mathematics classrooms.

Based on Mr. Brockway and Ms. Case’s classroom experiences, adaptations were made to the instructional unit. The team first defined their learning outcomes and aligned the lesson with the state’s mathematics standards. This component of lesson development was a new learning experience for Christie who is trained in mathematics and science. The learning outcomes were defined as follows: Students will be able to explain their responsibilities in maintaining and potentially decreasing energy consumption. Students will be able to interpret and create data tables and double bar graphs. An outline of this unit, the learning objectives and the connection between this unit and the standards is contained in Appendix A.

The unit began with an open discussion with the students on what they knew about energy and saving energy. Students were asked: Do electrical devices use energy and cost you money when they are turned off? Why is it important to turn off the lights when you are not in a room? And what do you think of when you hear the term saving energy? This activity was designed by Mr. Brockway and Ms. Case to elicit the background knowledge of their students. The discussion expanded to include the definition of electricity and from where electricity comes (primarily from burning coal), an area of knowledge that drew from Christie’s training and the summer workshop. Next, mathematics was introduced through watts, kilowatts and kilowatt hours. The students were shown energy bills, illustrating that all of these terms are used in this report. Students were further encouraged to ask their parents to show them their energy bill—bridging the gap between classroom instruction and the home. This was extended further to introduce engineering designs that increase the energy efficiency of our homes, such as solar panels or wind generation, CFL light bulbs, and multi-pane windows.

In teams of five, the participating students measured various electrical devices which were set up at five stations in the classroom. Using a worksheet as a guide, the students converted power (watts) to energy (kilowatt hours [kWh]) and then to cost per year. The students soon discovered that even devices that are in standby mode (turned off, but plugged in) consume energy. In fact, 5% of the United States' energy is consumed by "standby" devices, which equates to approximately \$1.37 billion dollars a year. This was a fact originally discussed during the summer workshop and caught the students' attention. How much money was their family's spending on standby devices? As a class, the number of households in the U.S. was calculated and the students determined that each household spends about \$60 annually on standby electricity. This led to a discussion of what they can do to reduce the energy used in their home (i.e. unplugging devices when not in use, turn off lights when leaving a room, and turning on water only when it is being used, etc.). As is illustrated in Appendix B, the computations completed by the advanced class were more mathematically complex than that required of the regular class. Additionally, all of the classrooms participated in a discussion which linked this exercise to careers in chemical, mechanical and electrical engineering. Through these activities, the participating students learned about energy and about the work of engineers. They further learned that engineers and engineering impact their everyday lives, and, more importantly, that they can think and act like engineers.

Lesson Impact: The initial impact of this unit was on 180 students in the participating classrooms. However, the students shared their enthusiasm for the unit with their friends, who shared the information with their mathematics teachers. Christie has now been invited to assist the two remaining sixth grade mathematics teachers in teaching the same unit. The total impact is approximately 350 students.

Assessment instruments were also used to measure impact. Based on a pre and post assessment, the instructional team learned that prior to instruction, 56% of students believed that turning devices off was sufficient for eliminating energy use. After instruction, all of the students understood that when some devices were in standby mode they were consuming energy. A response that illustrates students' misconceptions prior to instruction is as follows, "No because how is it going to waste electricity when it is turned off. It only uses electricity when it is turned on." This same student responded to the post activity as follows, "It is important to unplug devices because most of the devices when there off they still waste energy. So it is important to unplug devices because you save energy and money [sic]"

Workshop Impact: During the summer workshops evidence was collected in the form of a pre and post assessment of the participating teachers. Eleven teachers completed the pre and post multiple choice instrument. On average, the teachers responded correctly to 13 of 26 questions on the pretest and 19 of 26 questions on the posttest. This result was found to be statistically significant based on a paired, one-tailed t-test, with a p-value of less than .0001. Self-report instruments provided further support for this result.

Project Emulation: The unit that is described here has been fully developed and may be used by other classrooms. The devices described are easily available and only the Kill-A-Watt needs to be purchased or borrowed. Most universities with engineering departments have such a unit available for loan. Even a single “Kill-A-Watt” unit used in a classroom demonstration could have a significant impact on the introduction of electrical power as a finite resource and the concept of electrical conservation. Within the given school, two additional teachers have approached Christie with the purpose of emulating the unit in their classroom. The general design of the larger program can also be emulated by other school districts and universities. The National Science Foundation (NSF) encourages funded researchers to include outreach components in their research and we have learned that researchers happily join and contribute to well-designed programs. Additionally, we have designed and have implemented a parallel program for elementary schools in the participating district⁸ and are in the process of expanding this program to include additional school districts⁹. All of the summer units are also available for broad based use. In summary, this partnership can be emulated in part or in whole.

Overcoming Challenges, Lessons Learned and Successes: The major challenge of establishing a program such as this is cost. This challenge has intensified as a result of the recent decline in the economy. Our solution has been to build sustainability into the program as it was being developed. *Renewable Energy Materials Research Science and Engineering Center* on campus has recognized the value of this outreach program and contributes financially to its continuation (NSF, DMR-0820518)¹⁰. Several additional programs have expressed interest and collaborative proposals are pending. A major factor that influences this has been NSF’s encouragement that funded research programs include outreach.

Through this partnership, we have learned the importance of collaboration and flexibility in design. Teachers are the experts in their classroom. Faculty, engineers and scientists are experts in their content area. Valuing each is essential to the partnership’s success. The originally project was funded in 2003 in a different school district and a continuation award was funded to transfer this program to APS in 2007. Our efforts in the original school district are on-going, but due to funding, currently focus on the elementary school. Foundation funding has been secured, at the elementary level from Exxon Mobil, Denver Foundation, JP Morgan Foundation, Shell Oil Corporation, Boeing Corporation, and EPA Foundation. Efforts are ongoing to secure additional funding at the middle school level.

We have also learned that a single graduate student assisting a teacher for 7.5 hours per week is not enough. The participating teachers have on-going questions and interests that should be addressed. In the next several years, we will be expanding our programs to include interactive video links between participating schools and CSM. This will allow the participating teachers to consult with our graduate students, scientists and engineers directly throughout the academic

year, even when on-site meetings cannot be arranged. The piloting of this component of the project is being supported by Exxon Mobil Corporation¹¹.

Summary: As part of this panel presentation, Mr. Brockway, Ms. Chase and Christie will present the design of this partnership as well as the details of classroom implementation. Examples will be provided of jointly constructed classroom units and of students' products which have resulted from these efforts. This presentation will be designed to be interactive and hands-on in nature and will draw on the expertise of participating teachers, graduate students, faculty, engineers and laboratory scientists. Appendix A of this document contains an outline of the unit, appendix B provides the details of the lesson plan and Appendix C contains illustrative examples of student work. All of these will be discussed during the panel presentation.

Appendix A

Outline of Instructional Unit

OBJECTIVES:

1. Students will be able to collect data and present it in a table.
2. Students will be able to convert from watts to cost per year.
3. Students will be able to collect, organize, and represent data with a bar graph.
4. Students will be able to read, interpret and draw conclusions from bar graphs.
5. Students will learn that keeping some electrical devices plugged in still uses energy and costs them money.
6. Students will learn how to use the Kill A Watt device and how it can be used at home to help cut energy costs.

State's Mathematics Standard 2: Students use [algebraic methods](#) to explore, [model](#), and describe [patterns](#) and [functions](#) involving numbers, shapes, data, and graphs in problem-solving situations and communicate the reasoning used in solving these problems

State's Mathematics Standard 3: Students use data collection and analysis, [statistics](#), and probability in problem-solving situations and communicate the reasoning used in solving these problems.

BENCHMARKS:

3.1 Read and construct displays of data using appropriate techniques (for example, line graphs, circle graphs, scatter plots, box plots, stem-and-leaf plots) and appropriate technology.

3.1a: Read and construct displays of data including tables, charts, pictographs, line plots, bar graphs, and line graphs using a given set of data.

3.1b: Read, interpret, and draw conclusions from a line graph, bar graph, circle graph, and frequency table.

VOCABULARY:

1. **Table-** Mathematical information organized in columns and rows.
2. **Bar Graph-** A graph that uses horizontal or vertical bars to display countable [data](#).
3. **Watt-** A metric unit of power, used in electric measurements, to give the rate at which energy is used.
4. **Energy-** The ability to do work or the ability to move an object.

Appendix B

Lesson Plan Outline

Measuring Electricity

Lesson Plan

Materials Needed:

1. 6 Kill A Watt devices
2. 6 different power using devices (i.e. Fan, Laptop, Radio, Microwave, Refrigerator, Cell phone, etc.)
3. Table for each student with columns for: device, Watts on, Cost on, Watts off, Cost off. (The Last two pages contain a worksheet that can be used for this lesson plan)

Instructions:

1. What do the students know?
 - a. On the white board make two columns, one for Electricity and one for Energy/Saving Energy.
 - b. Ask the students what they know about each of these topics and write them on the board.
2. Background on Electricity
 - a. Where does electricity come from?
 - i. 49% coal, 20% natural gases, 19.4% nuclear, 7% hydroelectric, 3% oil, 2.3% other gases, 0.4% other renewables, 0.3% other
 - b. What is a Watt?
 - i. A metric unit of power, used in electric measurements, to give the rate at which energy is used.
 - ii. Explain that 1,000 watts=1 kilowatt
 - iii. Show pictures of the electric devices you will be testing and have kids guess how many watts they use.
3. Background on Energy and Saving Energy
 - a. What is Energy?
 - i. The ability to do work or the ability to move an object
 - b. How to Save Energy
 - i. When your cell phone is done charging unplug the charger from the wall
 - ii. Change to Compact Florescent light bulbs
 - iii. Use products with Energy Star labels
 - iv. Don't leave water running when you're not using it
 - v. Turn off lights and fans when you're not in the room

4. Kill A Watt Device
 - a. What the device is used for
 - i. It is used to act as a meter going between the item that draws the power and the power source
 - b. How to use the Kill A Watt
 - i. Plug the Kill a Watt into a wall socket
 - ii. Insert the plug for the electric device you want to test and turn the electric device on.
 - iii. Press the grey Watt button and record in your table the power reading.
 - iv. Repeat this process for when the device is turned off.
5. Converting to Kilowatts and Cost per year
 - a. $\text{kW} = (\text{Watt}/1000)$
 - b. $\text{Cost} = \text{kW} \times 24 \times 365 \times 0.11$
 - c. Convert each devices watt reading to kilowatts and cost per year and record the results in your table.
6. Graphing
 - a. After you have converted to cost per year make a bar plot of the data with device on the x axis and cost on the y axis. For each device make sure you plot the cost per year with device on and the cost per year with the device off.
 - b. Ask what conclusions can be made from the bar plot?

Measuring Electricity Lesson

Name: _____

Date: _____

1. Do you think that electrical devices (computer, xbox, etc.) use electricity and cost money when they are turned off? Why?

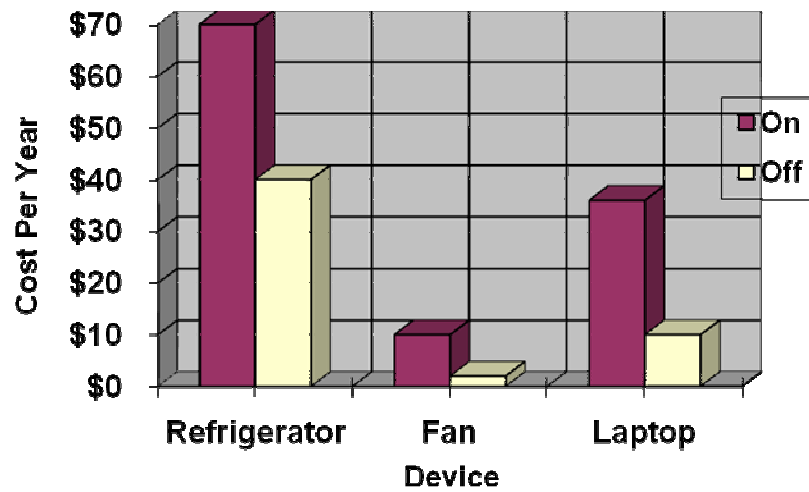
2. Use the KILL-A-WATT device to take the watt reading when the device in on and when the device is off and record it in the Measuring Electricity Table. Use a calculator to determine the cost per year when the device is on and when the device is off.

Measuring Electricity Table

Device	Watts On	Watts Off	Cost per Year On = Watts On x \$1.14	Cost per Year Off = Watts Off x \$1.14
Projector				
Hair Dryer				
Laptop				
Microwave				
VCR				

3. Use the data from your table to make a double bar graph. See Figure 1 for an example of how to make a double bar graph.

Figure 1



4. What conclusions can you make from your double bar graph? Is it important to unplug devices when you are not using them?

Measuring Electricity Table

Advanced Integrated Math

Device	On Watts	On kW (Watt/1000)	On Cost per day (kW x 24 x 0.11)	On Cost per year (Cost per day x 365)	Off Watts	Off kW (Watt/1000)	Off Cost per day (kW x 24 x 0.11)	Off Cost per year (Cost per day x 365)

Appendix C

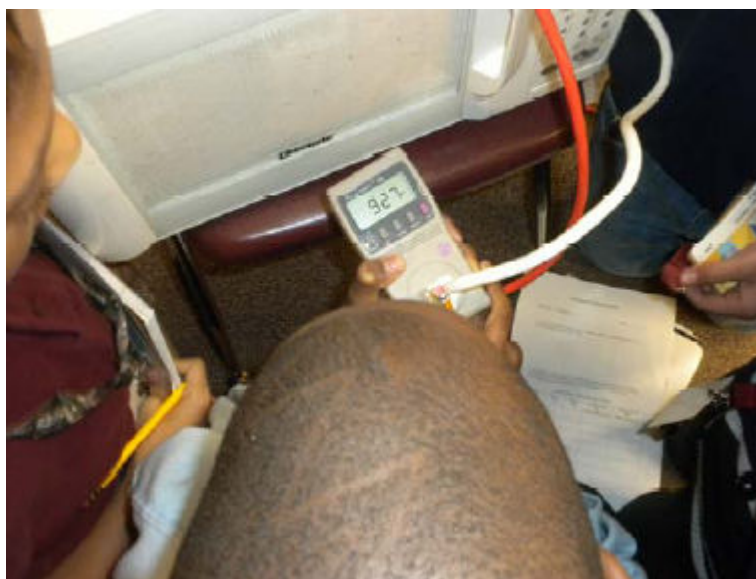
Examples of Student Work

This section contains photographs of the sixth grade students as they work on recording the data needed at each station and examples of worksheets completed by the sixth grade students.

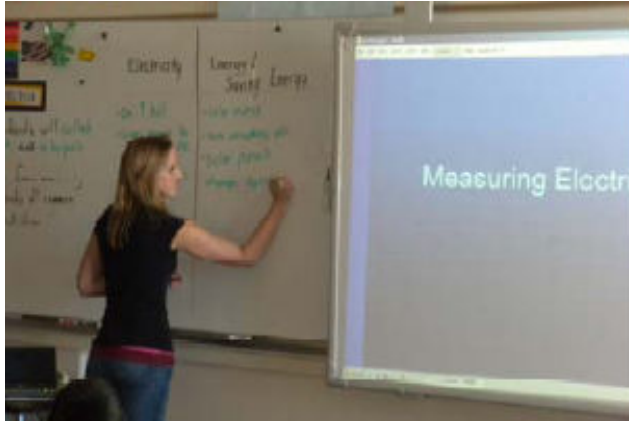
In the image on the left, students are recording the number of watts the VCR outputs when it is on and also the number of watts the VCR outputs when it is off. In the image on the right, the students are completing the same measurements for a microwave.



Here the students learn that when a purchased microwave states it has an output of 1,000 watts, this is an approximation rather than an exact measurement.



In the image on the left, Christie records the students' ideas on what they know about electricity, energy, and saving energy. In the image on the right, the students are asking Christie whether leaving the microwave on longer impacts the watts used. Christie encourages the students to test this idea.



The image below is of the sixth grade students using the Kill A Watt device to measure the amount of watts that the laptop computer uses when it is on and when it is off.



As the following student responses illustrate, most students incorrectly responded to the first question which was completed prior to instruction, indicating that electronic devices do not use energy when they are plugged in and turned off. After completing the experiment and calculations, the majority of students were able to explain that electrical devices do use energy in standby mode. The completion of the table and bar graphs provided evidence that the students are reaching the designated state standards.

Measuring Electricity Lesson

Name: _____

Date: 11/10/09

4

1. Do you think that electrical devices (computer, xbox, etc.) use electricity and cost money when they are turned off? Why?

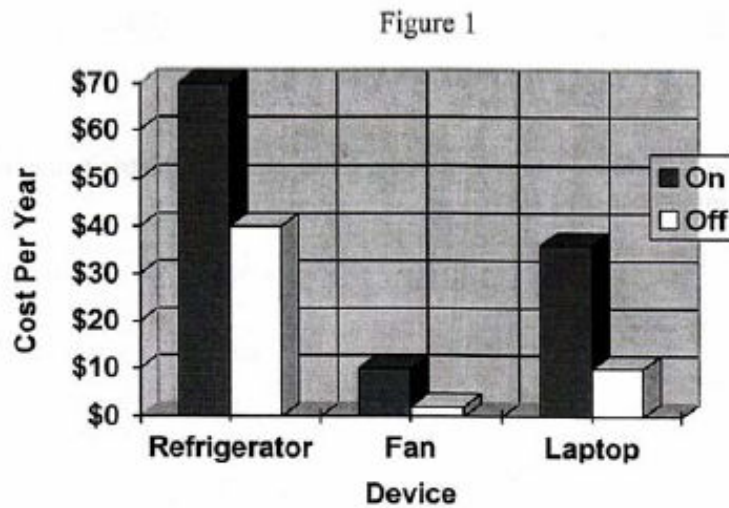
No because if it turn off then use not using it and its turn off when its turn off its not working which means its not using electricity then you don't have to pay.

2. Use the KILL-A-WATT device to take the watt reading when the device is on and when the device is off and record it in the Measuring Electricity Table. Use a calculator to determine the cost per year when the device is on and when the device is off.

Measuring Electricity Table

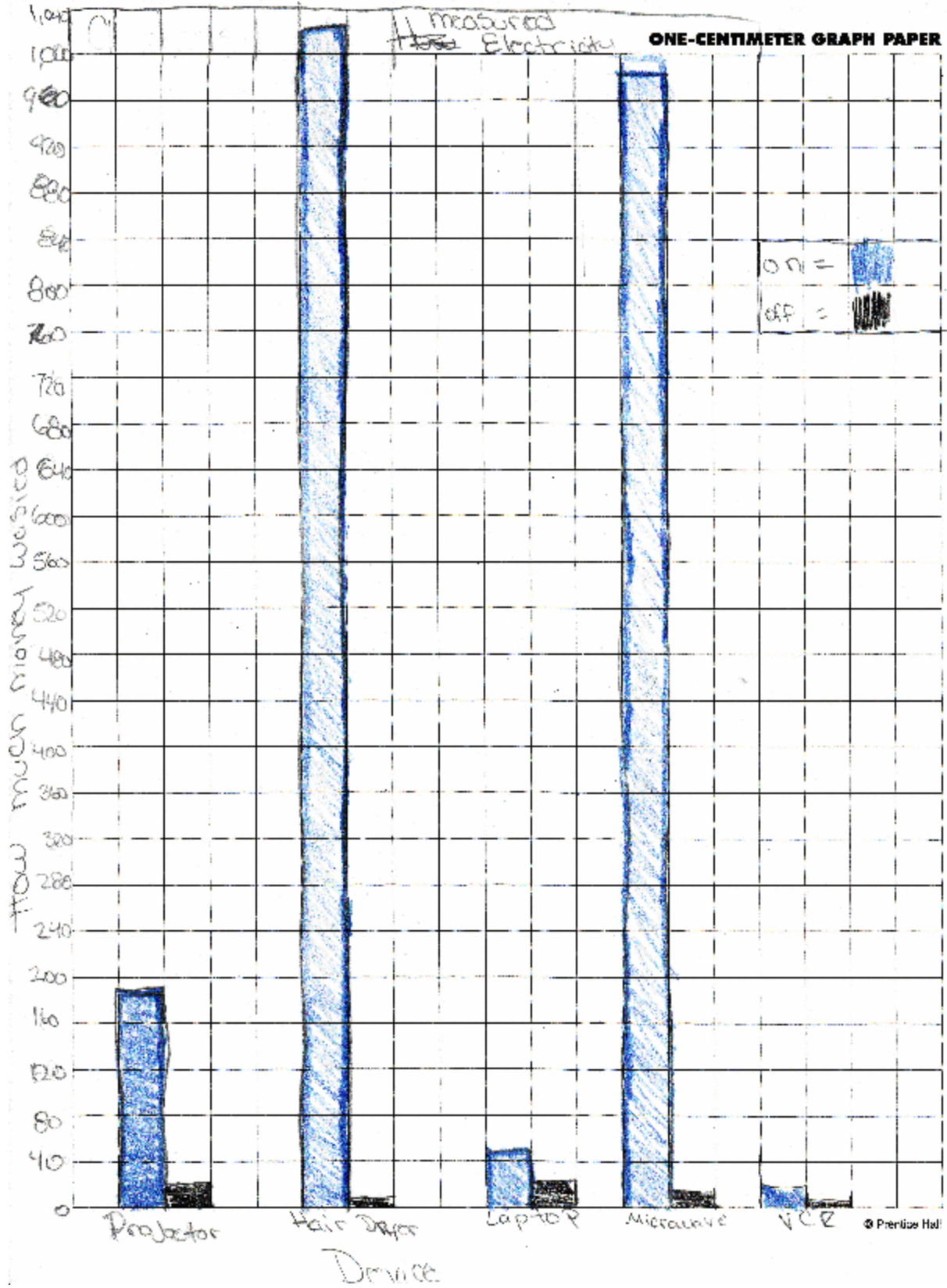
Device	Watts On	Watts Off	Cost per Year On = Watts On x \$1.14	Cost per Year Off = Watts Off x \$1.14
Projector	174 174	18	198.36 174 x 1.14 = 198.36	20.52 18 x 1.14 = 20.52
Hair Dryer	908	6	908 x 1.14 = 1035.12	6 x 1.14 = 6.84
Laptop	36	24	36 x 1.14 = 41.04	24 x 1.14 = 27.36
Microwave	875	63	875 x 1.14 = 997.50	63 x 1.14 = 71.82
VCR	13	6	13 x 1.14 = 14.82	6 x 1.14 = 6.84

2. Use the data from your table to make a double bar graph. See Figure 1 for an example of how to make a double bar graph.



3. What conclusions can you make from your double bar graph? Is it important to unplug devices when you are not using them?

Yes because if you don't you will be wasting more money. If you don't unplug, if you unplug you can have more money to save. Instead of having a high price of money but didn't even use it. That's why it's good to unplug things that you're not using.



2. Use the data from your table to make a double bar graph. See Figure 1 for an example of how to make a double bar graph.

3

Measuring Electricity Lesson

Name: _____

Date: 11-10-09

1. Do you think that electrical devices (computer, xbox, etc.) use electricity and cost money when they are turned off? Why? *No because if their not running then you won't need to worry about the money cost. But if they are on then you will need to worry about the money cost.*

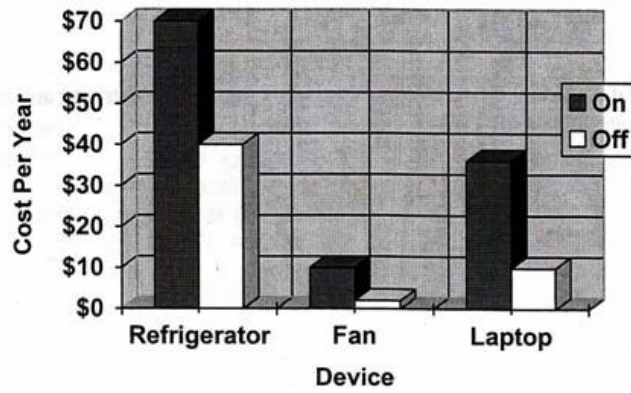
2. Use the KILL-A-WATT device to take the watt reading when the device in on and when the device is off and record it in the Measuring Electricity Table. Use a calculator to determine the cost per year when the device is on and when the device is off.

Measuring Electricity Table

Device	Watts On	Watts Off	Cost per Year On = Watts On x \$1.14	Cost per Year Off = Watts Off x \$1.14
Projector	176	18	200.64	20.52
Hair Dryer	880	0	1003.2	0
Laptop	35	19	39.9	21.66
Microwave	851	3	970.14	3.42
VCR	13	6	14.82	6.84

2. Use the data from your table to make a double bar graph. See Figure 1 for an example of how to make a double bar graph.

Figure 1



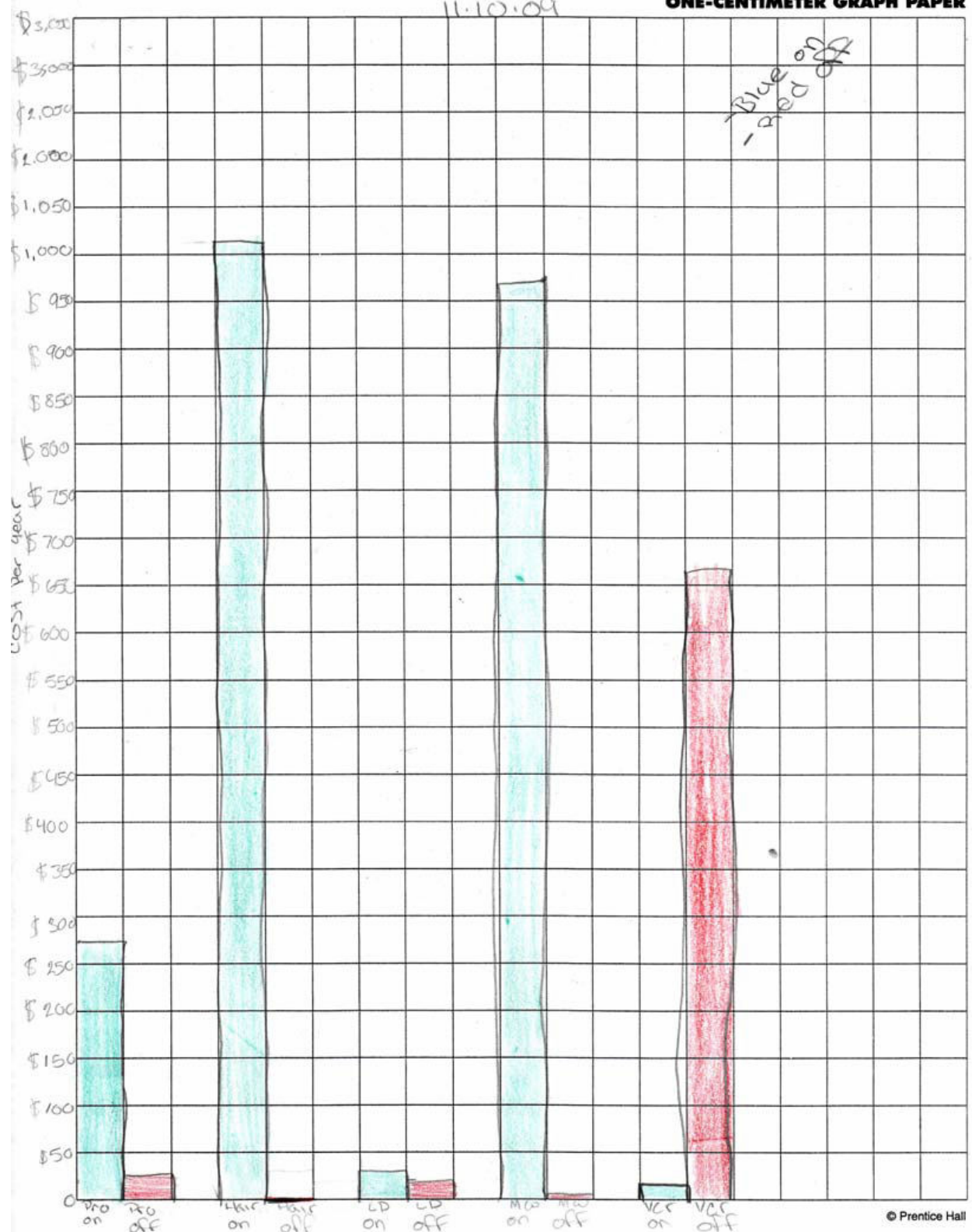
3. What conclusions can you make from your double bar graph? Is it important to unplug devices when you are not using them?

Yes because you will need to pay bill that are way over your budget and even if there off they still use electricity.

on off

11.10.09

ONE-CENTIMETER GRAPH PAPER



Blue on
Red off

Device

© Prentice Hall

Measuring Electricity Lesson

Name: _____

Date: 11/10/09

1. Do you think that electrical devices (computer, xbox, etc.) use electricity and cost money when they are turned off? Why?

I think yes because even though your computer and xbox are turned off. They are still plugged in and are still running on electricity, because they are still plugged in.

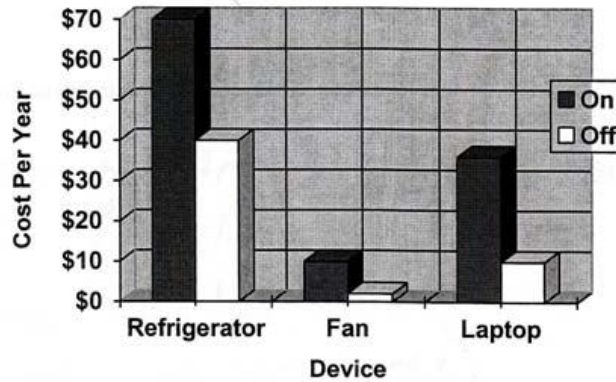
2. Use the KILL-A-WATT device to take the watt reading when the device is on and when the device is off and record it in the Measuring Electricity Table. Use a calculator to determine the cost per year when the device is on and when the device is off.

Measuring Electricity Table

Device	Watts On	Watts Off	Cost per Year On = Watts On x \$1.14	Cost per Year Off = Watts Off x \$1.14
Projector	172	20	$172 \times 1.14 = 196.8$ $196.8 - (19)$	$20 \times 1.14 = 22.8$ $22.8 - (22)$
Hair Dryer	894	00	$894 \times 1.14 = 1019.16$ $1019.16 - (102)$	$00 \times 1.14 = 00$ $00 - (0)$
Laptop	34	23	$34 \times 1.14 = 38.76$ $38.76 - (39)$	$23 \times 1.14 = 26.22$ $26.22 - (26)$
Microwave	851	03	$851 \times 1.14 = 970.14$ $970.14 - (970)$	$03 \times 1.14 = 3.42$ $3.42 - (4)$
VCR	13	07	$13 \times 1.14 = 14.82$ $14.82 - (15)$	$07 \times 1.14 = 7.98$ $7.98 - (8)$

2. Use the data from your table to make a double bar graph. See Figure 1 for an example of how to make a double bar graph.

Figure 1



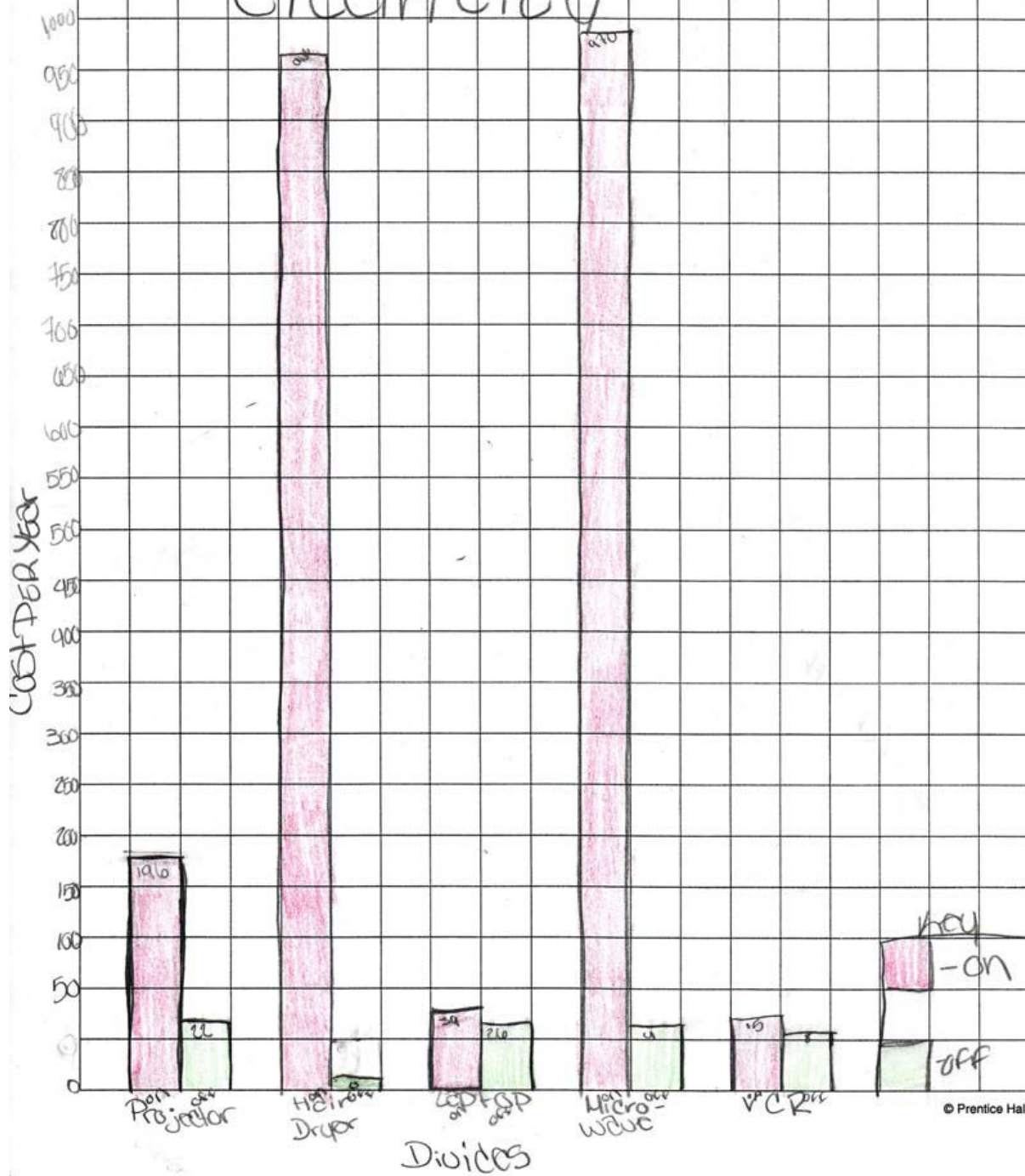
3. What conclusions can you make from your double bar graph? Is it important to unplug devices when you are not using them?

It is important to unplug devices when you are not using them because you save more money rather than losing more money. When you unplug devices when you are not using them at the same time you are helping yourself when you unplug the devices you are not using.

11/10/09

ONE-CENTIMETER GRAPH PAPER

MEASURING Electricity



© Prentice Hall

Measuring Electricity Lesson

Name: _____

Date: _____

1. Do you think that electrical devices (computer, xbox, etc.) use electricity and cost money when they are turned off? Why?

No because how is it going to waist electricity when its turn off because only uses electricity when its turned on.

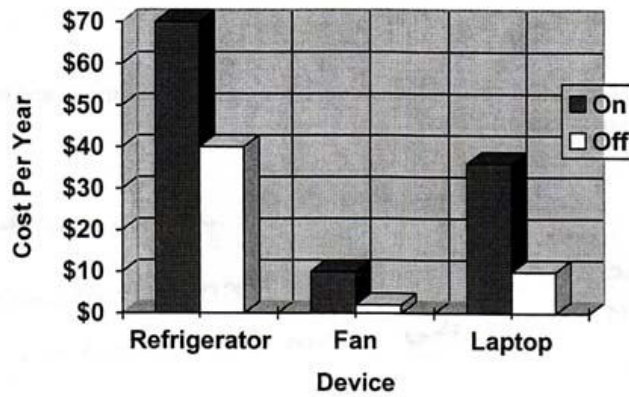
2. Use the KILL-A-WATT device to take the watt reading when the device in on and when the device is off and record it in the Measuring Electricity Table. Use a calculator to determine the cost per year when the device is on and when the device is off.

Measuring Electricity Table

Device	Watts On	Watts Off	Cost per Year On = Watts On x \$1.14	Cost per Year Off = Watts Off x \$1.14
Projector	174	7	\$198.36	\$7.98
Hair Dryer	924	0	\$1053.36	\$0
Laptop	39	24	\$44.46	\$27.36
Microwave	957	3	\$1090.98	\$3.42
VCR	13	67	\$14.82	\$7.98

2. Use the data from your table to make a double bar graph. See Figure 1 for an example of how to make a double bar graph.

Figure 1



3. What conclusions can you make from your double bar graph? Is it important to unplug devices when you are not using them?

it is important to unplug devices because ~~most of the~~ devices when there off they still was it energy. so its important to unplug devices because you save energy and money.

HIGH SCHOOL WINNER

High School Collaboration

Brian Lein, Princeton High School, Cincinnati, OH

Eugene Rutz, University of Cincinnati, OH

The Initial Partnership

Beginning in 2006, Mt Notre Dame High School, Princeton High School, Mother of Mercy High School, and Harrison High School collaborated with the College of Engineering at the University of Cincinnati on the design, development and implementation of a program to introduce students to the practice of Engineering and Engineering Technology¹². A working group was formed in 2006 with the goal of providing high school students a meaningful introduction to the practice of engineering. The working group established the goal for the program to be that *greater numbers of students would understand the practice of engineering and engineering technology and would choose to pursue these in their college studies*. The partners concluded that a course that provided a project-based approach to presenting the material would facilitate the program goal.

The core group was composed of a high school biology teacher, a high school physics teacher, a high school technology education instructor, and a program administrator (with significant experience in the practice of engineer) from the College of Engineering who chaired the meetings. All partners contributed to the identification and creation of relevant and appropriate projects, lesson plans, rubrics and instructional materials. The partners built in significant flexibility in the project activities so that the course could meet the needs of very different schools. A course was created and offered at four schools for the first time in the 2007 – 08 school year.

The Partnership Today

Eight area high schools (including two large public schools, two smaller public high schools and four all-girls schools) are currently part of the collaboration.

In the implementation of the course the role of the high school instructors is to lead the in-class sessions and project-based activities. It is the role of College faculty and staff to provide instructional modules to introduce engineering disciplines, concepts important to specific disciplines, and concepts that span disciplines (e.g. engineering design, communication, teamwork). The instructional modules are created as streaming media files and made available to the students via a web site allowing access at the schools' (and students') convenience.

The partnership has proven to be quite organic in that as needs and opportunities arise, the roles of the partners change to meet these. In general, the College partners provide the instructional content while the high school teachers provide classroom management and facilitation of classroom projects. However, there are times when these roles are reversed. The partnership is sustained and flourishes because of the shared goal and the commitment to providing opportunities for students.

High school and college partners work together to identify opportunities for the students to interact with working professionals and to visit engineering organizations. This has resulted in visits to work sites, presentations by engineers from various occupations, panels of women professionals fielding questions at the all-girls schools, and classroom visits by engineers and engineering students to help with project-based activities. A social networking site was also created to facilitate interaction and sharing of resources.

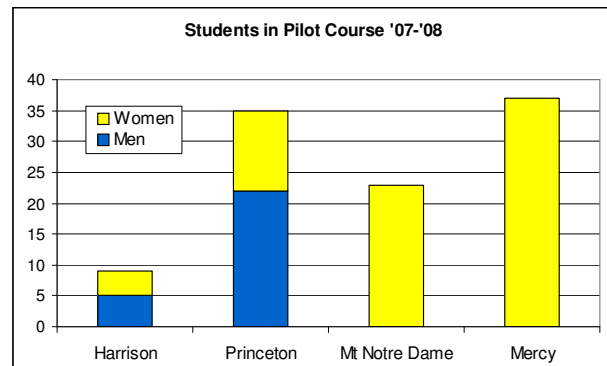
Overcoming Challenges

The collaborators continue to meet as the course is presented to share lessons learned, to discuss classroom issues and their resolution, to identify gaps in the materials, and to identify additional resources. If a need is identified as the course is presented, email communication is used to discuss the issue and identify potential solutions. Several examples of issues resolved during the course:

- The need for an assessment rubric was expressed by one teacher. Another teacher had developed one based on a similar project and she shared this with all the partners.
- One school's CAD resources were inadequate. The college partner identified the opportunity for schools to receive free software through a corporate grant. The school now has 3-D modeling software.
- Another school wanted to build sterling engines as a project but the students did not have sufficient background in basic thermodynamics or heat engines. The college partners developed instructional modules on those topics and made them available to all the schools.

Outcomes

In the pilot year of the program, four schools offered the course and over 100 students benefited. As illustrated in Figure 1, most of these students were women. At one school, 11 of the 23 women participating indicated they are planning on studying engineering in college. There are currently over 200 students participating in the program at 8



different schools.

This model of a local university working with local schools, and local schools supporting each other, has enabled the program to succeed and to grow to additional schools, benefiting growing numbers of students.

Successes realized during the first two years of the program include:

- Students are surveyed regarding their intention to pursue engineering, technology and science after high school. On a post-course survey, 63.8% of the students planned on studying engineering, technology or science - a 17% increase over the pre-course survey.
- Through the projects, high school instructors better appreciate that students use skills from a variety of subjects to complete the projects. As a result of this, Princeton High School has adopted a more collaborative approach to teaching the course. The course is taught by a technology education teacher with significant experience in project-based instruction. The teacher coordinates lessons with his colleagues who teach physics and chemistry so the concepts are reinforced. A high school English instructor comes to the class to discuss communication and making effective presentations.
- The partnership identified the opportunity for schools to acquire solid modeling software. Mt Notre Dame High School wrote a successful grant to acquire the software. This was used during the program. Based on the experience, the school instituted a “design summer camp” to introduce young women to solid modeling, design and the modern tools engineers use to perform these functions.
- Collaborators have instituted regular meetings to share resources, teaching materials, and lessons learned from the projects and teaching methods employed. These informal meetings have been a significant benefit to teachers and encouraged sharing of materials between schools.

Student feedback on the course included these themes:

- “I learned a lot about different engineering fields. I also learned how to spot weld, solder, and connect electrical circuit boards, water proof a motor and a lot more. I am glad to have taken this class and I am really considering taking on a field in engineering.”
- “I learned many things such as what engineers do as well as the different types of engineering. I came into this course with interest in engineering but I didn't know whether I wanted to be a structural, civil, or mechanical engineer. Through the projects we did in this class I determined that mechanical is definitely the type of engineering for me.”
- “I learned problem solving and team work skills. I also had the opportunity to build things - I would never have this opportunity in another class”
- “I learned how to communicate better and give a good presentation. I learned how to be an efficient team member and also leader.”

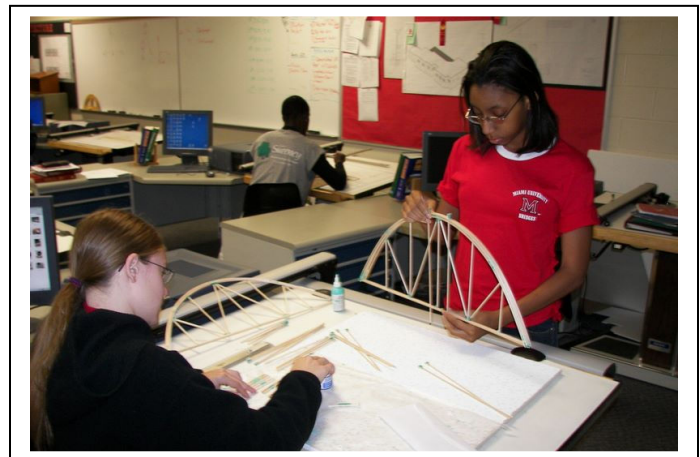
Student Projects

The course is project based so students participate in a wide array of projects designed to help them understand the practice of engineering and the connection between math, science, technology and engineering. Projects associated with each engineering discipline are included as are projects related to teamwork, creativity, and design. Projects typically require a product, a written report and a presentation. Projects completed by students included: cell phone design; design, construction and testing a bridge prototype; design and prototype of a prosthetic leg; design, build and test a machine to count the number of licks it takes to get to the center of a tootsie roll pop; design, build and demonstrate iPod amplifier and speakers; and many more.

Two projects and student reactions are described below.

Bridge Building Project

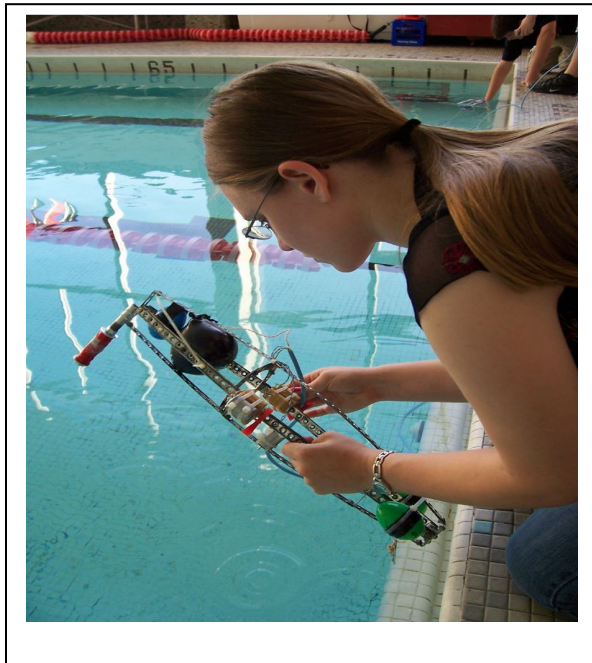
This project was performed during the unit on Civil Engineering. The students were to design and construct a bridge that met given specifications and which had a number of constraints. Students were introduced to civil engineering and principles of civil engineering including analysis of simple trusses. Students were also presented an instructional module on vectors that related concepts they had learned in high school math with their use in solving engineering problems. Student then tested the load carrying capacity of their prototype design.



One student wrote regarding the best aspect of the course *“My favorite part of this course was the bridge building project. The reason why is because we got to really be creative and it was fun to build. We did not have to follow the same design as everyone else so we got to use our creativity.”* This same student had this to say regarding the course *“What I learned from this course is all the different fields in engineering and also how to work better in them. This course has helped me decide what I want to do for my college degree. The team work aspect of this class has better prepared me how to communicate with people. I will now be able to go into the business world and hopefully be successful communicating with my co-workers or classmates.”*

Remotely Operated Underwater Vehicles

The purpose of this unit was to study marine engineering and related fields through the design, construction and testing of underwater remotely operated vehicles (ROVs). In order to develop interest in the topic, students studied the work of Jacques Cousteau and Robert Ballard of the JASON Project¹³. As part of the engineering design process, students were asked to brainstorm at least 10 different ideas for underwater ROVs. Students also had to sketch their ideas and describe assembly plans.



The ROVs include an electromagnet that allowed them to pick up washers at the bottom of the school's indoor pool. Designs were tested to determine their ability to maneuver and retrieve five washers. The student teams also prepared reports and gave presentations on their projects. The project has been published in the *Technology Teacher*, a publication of the

International Technology Education Association¹⁴.

Best Practices

In terms of developing a program that has high impact, we offer these as best practices:

- *Affordable* - schools should be able offer the program with existing resources and staff. Only modest resources for training or purchasing supplies or materials should be necessary.
- *Adaptable* - the program needs to be flexible enough to accommodate the variations in resources, student populations and expectations that exist in different schools.
- *Accessible* - keep pre-requisite knowledge to a minimum so that as many students as possible can participate.

In terms of the partnership, we offer these as best practices:

- *Shared goals* –while individual schools varied in target student population and program implementation, all partners shared the fundamental goal of increasing participation in engineering and technology.
- *Commitment* – schedules are full and grant funds (if they are available at all) run out. If partners are not committed to implementing a program, it won't happen.
- *Continuity* – continuing to meet together provided a forum for learning from each other and supporting each other in the implementation of the program and the continuing improvement of the program.

- *Communication* – in particular, email communication provides an effective mechanism to stay connected and share materials between partners.

In terms of engaging students, we offer these as best practices:

- *Hands-on* – the project-based approach was effective at engaging students.
- *Connections* – help students understand the relationship between the projects, materials that students have learned (math and science) and the practice of engineering.
- *Duration* - keep most projects to less than 3 weeks.
- *Problem Solving* – use projects that solve a problem rather than just produce something; the sense of accomplishment and engagement is greater.



Continuing the Collaboration

Through careful and purposeful design of the program, the course has proven to be scalable with the number and types of participating schools continuing to grow. For the 2010 – 2011 academic year the collaboration will include:

- Public schools with predominantly Caucasian students
- Public school with predominantly minority students
- Public school with large rural population
- Private all girls schools
- Private all boys school

Instructional materials and resources are being migrated to an open wiki in addition to a course management system. This will reduce the burden on university IT staff and allow easier access for some students and schools. The wiki design will provide an easier mechanism for collaborators to add content, modify materials, and share resources. The open source will also be easier to find for other schools interested in such programs.

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