

## **AC 2009-426: A PARTNERSHIP BETWEEN CAPSTONE DESIGN AND K-12 OUTREACH**

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## **A Partnership between Capstone Design and K-12 Outreach**

### **Introduction**

The nation continues to face a shortage of engineers. Concurrently, public schools are struggling financially and making severe budget cuts which significantly impact STEM enrichment programs. This can lead to even a further reduction of potential engineers in the pipeline. The mechanical engineering design program at Michigan State University has addressed this issue by partnering with a local elementary school on capstone design projects. A team of mechanical engineering students work with the 5<sup>th</sup> grade class at the local engineering magnet school on their capstone project that addresses a school equipment need. Projects have included a solar heating system for a worm-based compost system, a global warming demonstrator, and a solar thermal collector experiment. In addition to completing the technical design project, the engineering students present several lessons to the 5<sup>th</sup> grade class addressing the engineering design method and the basic science concepts of the design project. The design team also develops a web site with activities intended to engage the 5<sup>th</sup> graders in the project.

The coupling between a capstone design experience and K-12 outreach is not unique. Electrical engineering students at the University of Cincinnati performed their capstone project as part of the NSF STEP Fellows program [1]. At Western Michigan University, the Engineering Design Center for Service-Learning addresses equipment needs for K-12 schools with combined teams of both engineering and education students [2]. However, a long term relationship with a fifth grade class as reported in this paper is unique.

This paper shares the development of this partnership, including the initial contacts, the solicitation of funding, and the identification of projects. Descriptions of the projects are provided. Finally, feedback from all participants is provided. The paper should serve as a guide to other programs that wish to pursue these sorts of partnerships.

### **The Partners**

Woodcreek Elementary School is one of four elementary level magnet schools in an urban school district. As a magnet elementary school, the curriculum focus is math, science, and engineering. Teachers consistently incorporate hands-on materials and activities to help students grasp technical concepts. One instructional position is dedicated to the school's Engineering Center, and this teacher leads these hands-on activities. The school has several recycling projects and is dedicated to instilling in its students a green mentality. As an urban school, the student makeup is extremely diverse with approximately 80% of the students being minorities.

ME 481 serves as the capstone design course in the mechanical engineering program at Michigan State University. Student teams of 3 to 5 members are assigned real world projects for the semester. Most of these projects are sponsored by industry, but each semester a few are humanitarian projects that look to serve the community. Some previous projects have linked the capstone course with a public school through the design of devices to assist children with physical disabilities. These have included a recumbent cycle, a shower cart, and a desk chair.

The first of the partnership projects came about due to the publicity of one of these humanitarian capstone projects, Solar Ovens for Tanzania. The engineering teacher at Woodcreek read the

newspaper article on the solar oven project and emailed the instructor of the ME 481 class inviting him to attend a celebration on the completion of a new worm base compost bin for the school. While he was in attendance, the engineering teacher briefed him on the winter freeze problem of the worm bin and solicited his help to solve the problem. It was agreed that a capstone design team would be assigned the next semester to work on the project.

## The Projects

There have now been four capstone design projects, since the initiation of this partnership. Each one is discussed below. Because of funding and the elementary school's commitment to a Green philosophy, it was decided that the projects should emphasize energy and the environment. The projects are determined during a meeting between the Woodcreek teachers and the capstone instructor at the end of the previous semester. The 5<sup>th</sup> grade science curriculum for the upcoming semester is discussed and the group brainstorms on what sort of teaching aide might be useful in support of the curriculum. A project proposal is then drafted, which is included with the project description packet distributed to the capstone class on the first day of class. A sample proposal is shown in Figure 1.

### Figure 1 Typical Project Proposal

#### Capstone Design Project Proposal

##### ME 481 Mechanical Engineering Design Projects

Project Sponsor (Company Name): Woodcreek Elementary School/Motorola Foundation

Name of Professional Advisor: Sandy Raymer, Diane Graham

Project Title: Wind Power Demonstrator

Address: 4000 Woodcreek Lane, Lansing MI

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Diane.Graham@lansingschools.net

**PROJECT DESCRIPTION** (Please **append additional sheets** of text describing the project. Indicate if a confidentiality and/or intellectual property agreement will be required.)

One of the units covered in the fifth grade curriculum at Woodcreek Elementary School (an engineering and science magnet school) is energy, weather, and wind power. Certainly an important topic to be covered is the conversion of wind energy into electric power. It is well known that a hands-on experience greatly facilitates student learning, even more so with a complex topic such as wind power. The student team will design, build, and implement a classroom demonstration system of a wind power system.

A principal part of the design activity will be to interact with the fifth grade classes at Woodcreek. This interaction will not only include engaging the Woodcreek students in the development, design, and construction of the wind power demonstration system, but will also involve several presentations to the class on the basics of energy, wind energy, conversion of mechanical work to electric energy, the engineering design method, and the engineering profession.

This project will serve as this semester's Motorola Youth in Energy and Environment Humanitarian Project.

The projects are divided into two main parts: technical and educational. The technical aspect of the project includes the design, build, and implementation of a teaching aide in support of the 5<sup>th</sup> grade science curriculum. The educational aspect of the project involves teaching the fifth grade class on applicable engineering topics, as well as including the class in the design and build of the teaching aide.

### **Solar Heated Worm Compost Bin for Woodcreek Elementary School (Fall 2007)**

Students at Woodcreek Magnet Elementary School dispose of their lunch waste through a worm-based compost bin. Worm composting is a beneficial process because it reduces the amount of natural waste that would otherwise be put into a landfill. During the warm months of the year the worms consume the lunch waste and produce compost. During the winter months, however, the worms go into hibernation and composting ceases. It has been proposed that the heat of the sun can be used to warm the compost bin during the winter months, allowing the worms to continue composting.

This project was divided into two main parts: technical and educational. The technical aspect of the project included the design, build, and implementation of a solar heating system for the worm compost bin. The educational aspect of the project involved teaching the fifth grade class on applicable engineering topics as well as including the class at Woodcreek Elementary in the design and build of the solar heating system. A picture of the final system is shown in Figure 2.

**Figure 2 Final Solar Heating System**



### **Global Warming Demonstrator for Woodcreek Elementary School (Spring 2008)**

Weather is one of the topics covered in the 5<sup>th</sup> grade curriculum. With Woodcreek school's interest in energy and the environment a teaching aide to demonstrate global warming was designed and constructed. The teaching aide consists of a Plexiglas box and demonstrates the impact of CO<sub>2</sub> levels on the earth's temperature. A heat lamp inside the box simulates the sun. Blankets are used to simulate the thermal insulating affect of CO<sub>2</sub> and a correlation is developed between the number of blankets and the atmospheric CO<sub>2</sub> concentration. Model train features were incorporated into the bottom of the box to draw the 5<sup>th</sup> graders attention. An ice block may be placed in the box to simulate a glacier and the 5<sup>th</sup> grade class can measure the melting rate. A picture of the final system is shown in Figure 3.

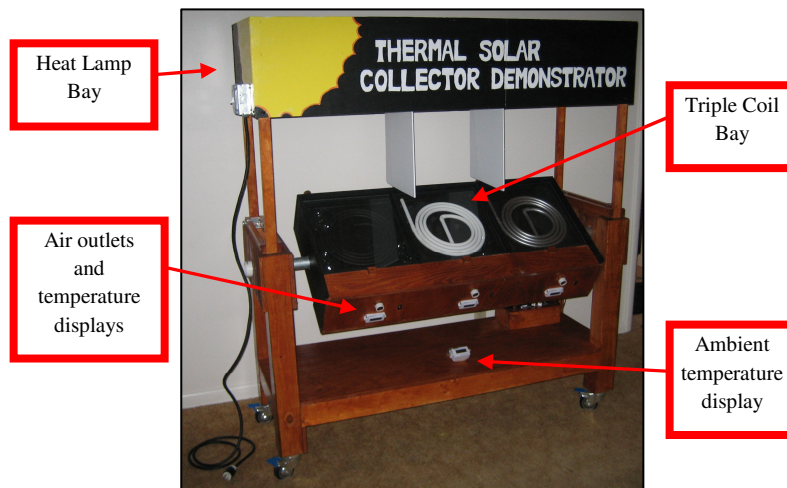
**Figure 3 Global Warming Demonstrator**



**Thermal Solar Collector Demonstrator for Woodcreek Elementary School (Fall 2008)**

A spring project carried out by the 5<sup>th</sup> grade class involves the design and build of solar cookers. In support of this project and instruction in solar energy, a project focused on the development of a thermal solar collector demonstrator was undertaken. The demonstrator allows several different solar issues to be investigated including surface condition, insulation, and sun orientation. The demonstrator is equipped with heat lamps to simulate the sun, but the demonstrator is mobile and the lamps can easily be removed, so that the actual sun can be used. A picture of the final system is shown in Figure 4.

**Figure 4 Thermal Solar Collector Demonstrator**



**Wind Power Demonstrator for Woodcreek Elementary School (Spring 2009)**

The teachers at Woodcreek have taken the initial steps in obtaining an actual wind turbine for the school. A teaching aide that will demonstrate wind power issues and support this endeavor is the capstone project for the current semester.

In the implementation of these four projects a relatively standard approach to the educational component of the project evolved. The capstone team conducts six lessons with the 5<sup>th</sup> grade class. The general nature of these lessons is as follows:

Lesson 1: The capstone team introduces themselves to the team, presents the engineering design method, and receives input from the 5<sup>th</sup> grade students about the project.

Lesson 2: This lesson serves as the first project presentation for the capstone course, which is focused on problem recognition. The capstone team explains the physical aspects of the problem and solicits ideas from the 5<sup>th</sup> grade class.

Lesson 3: The capstone team covers the main scientific principle of the project, for example energy transfer for the Thermal Solar Collector Demonstrator. This is typically done with a hands-on activity.

Lesson 4: This lesson serves as the second project presentation for the capstone course, which is focused on synthesis and decision making. The capstone team presents all of the design alternatives, evaluates the design, and make a recommendation to the 5<sup>th</sup> grade class.

Lesson 5: In this lesson another major scientific principle of the project is addressed, again with an interactive activity.

Lesson 6: This is a wrap-up lesson at which the capstone team tries to assess the level of understanding on the project the 5<sup>th</sup> grade class about the project. The Global Warming team used a Jeopardy type game with answers dealing with global warming issues and principles.

Design Day Presentation: At the end of the semester the College of Engineering hosts a design showcase at which many of the design courses in the College present their work. This takes place on the Michigan State University campus. The Woodcreek 5<sup>th</sup> grade class is bussed to the campus and attends the capstone team's formal final presentation, in addition to participating in several of the other activities.

Lesson 7: During final exam week the capstone team brings the teaching aide to Woodcreek and demonstrates it to the 5<sup>th</sup> grade class.

Each of the lessons at the elementary schools runs for approximately 30 minutes. The capstone team also creates a web site for the 5<sup>th</sup> grade class that provides class activities for weeks that the capstone team does not come to Woodcreek. For the three compiled projects the web sites are:

<http://www.egr.msu.edu/classes/me481/course/SolarWorms/>  
<http://www.egr.msu.edu/classes/me481/course/GlobalWarming/>  
<http://www.egr.msu.edu/classes/me481/course/SolarCollector/>

This partnership is funded through a grant from the Motorola Foundation. Early in the first project the capstone instructor was made aware of a grant solicitation put forward by the

Motorola Foundation. The objectives of the partnership aligned very well with the interest of the Motorola Foundation. A proposal was written asking for 3 years of funding at \$15,000 a year. While waiting to hear from the Foundation, the capstone instructor identified several other funding possibilities, including the foundation for the local energy company. The Motorola Foundation proposal was funded in full. A major selling point involved the urban nature of the elementary school and its large minority population (approximately 80%). Another important factor was recruiting the assistance of alumni at Motorola in support of the proposal.

### Evaluation of the Partnership

It is difficult to assess the impact of an outreach program similar to this one due to the long time constant. That is, 5<sup>th</sup> graders will still have 6 years of school prior to entering college and perhaps majoring in engineering. To measure the 5<sup>th</sup> graders learning directly on the topics of the projects, a survey was conducted. The survey and results conducted by the Solar Heated Worm Compost Bin team is shown in Table 1.

**Table 1. Semester Wrap Up Results**

<b>Semester Wrap Up Results</b>						
5: Exceptional Reponse 3: Good Response 1: No Comprehension						
Question	Class Average	Group 1	Group 2	Group 3	Group 4	
<b>Lesson 1</b>						
1	What is Engineering?	4.5	5	4	5	4
2	What is Mechanical Engineering?	3.5	3	4	3	4
3	What do engineers do?	4.25	3	4	5	5
4	Why are engineers important?	4	3	3	5	5
5	How can you become a Mechanical Engineer?	4.5	4	5	5	4
6	Why do you want to become a Mechanical Engineer?	4.25	5	4	3	5
<b>Lesson 2</b>						
7	What is vermicomposting?	3.75	3	4	3	5
8	What are the benefits of the worm bin?	4.25	3	4	5	5
9	Discuss the Design Process	4	5	4	4	3
<b>Lesson 3</b>						
10	What is energy?	4.5	5	5	4	4
11	Name different types of energy	4.75	4	5	5	5
12	How is energy transported?	3.25	4	3	3	3
13	Discuss the ball dropping & turbine activities	3.25	3	5	2	3
<b>Lesson 4</b>						
14	What were the design alternatives?	3.5	4	3	4	3
15	Why did we choose the solar collector system?	4	5	3	5	3
16	How do you conserve energy?	4	5	3	4	4
<b>Lesson 5</b>						
17	What is solar energy?	4	5	5	3	3
18	Name some examples of solar energy	4.25	5	4	4	4
19	What are two forms of solar energy?	3.5	3	4	4	3
20	What is a solar panel?	4.5	5	5	4	4
21	Why do we have seasons?	4.5	5	5	4	4
22	How did we decide the angle of the solar collector?	3.25	4	3	3	3

It is apparent from Table 1 that the students' knowledge of the engineering topics discussed in the lessons has increased significantly since the beginning of the school year. The class averages



for each question were all above 3, meaning that the majority of the class answered the wrap up questions well and confirmed understanding of the discussed topics. The class demonstrated the highest level of understanding in lesson 3 when the students were asked to name different types of energy. Similar results have been obtained from the other projects.

Reaction from the capstone team members has been very positive. All have expressed appreciation in the opportunity to participate in such a unique project. There are always many potential teams that apply for the Woodcreek project.

The instructional staff at Woodcreek and the capstone instructor have developed a very close relationship. The capstone instructor participates in many activities at Woodcreek, including a magnet school recruiting fair, career day, and other school functions.

### **Observations and Conclusions**

A successful partnership has been established that combines the capstone design experience with elementary school outreach. Factors contributing to the success include:

- Shaping the 5<sup>th</sup> grade curriculum toward the capstone project.
- Enthusiasm of the elementary school staff to participate in the partnership
- Commitment of the capstone instructor to elementary school activities beyond the capstone project
- Funding from the Motorola Foundation

One major challenge that exists is to more fully use the teaching aides that have been developed through the capstone projects.

### **References**

1. Davis, Karen C., Perkey, Megan L., Harth, Nicholas B., and Dees, Nathan, "STEPing into the Classroom: An Alternative Capstone Experience", **Proceedings of the 2005 ASEE Annual Conference and Exposition**, Portland, June 2005.
2. Kline, Andrew, Tsang, Edmund, and Aller, Betsy M., "Service-learning Engineering Design Activities at Western Michigan University to Support K-12 STEM Education", **Proceedings of the 2005 ASEE Annual Conference and Exposition**, Portland, June 2005.