# AC 2010-1618: GO GREEN - USING SUSTAINABILITY ENGINEERING IN A MIDDLE SCHOOL SUMMER PROGRAM

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# Go Green – Using Sustainability Engineering in a Middle School Summer Program


## Abstract

The Go Green Institute is an interdisciplinary collaboration of engineers, scientists, and educators serving fourteen middle-school school districts in southern New York. The institute's aim is to increase students' understanding of science concepts and skills related to environmental sustainability and broaden students' perceptions of engineering, science, and math careers through a range of exciting activities that students do not experience in school. The resulting 10-day learning experience integrates (1) Biology/Life Science, (2) Chemistry/Physical Science, and (3) Math/Engineering by framing instruction and activities around climate change and sustainability issues. Students participated in advanced coursework in the form of interactive content sessions, fieldtrips and guest speakers, and experiments/team projects.

As part of the evaluation plan for the Go Green Institute, pre-experience and post-experience assessments were administered to the participating students to determine whether or not measurable change in knowledge and skills could be detected as a result of the institute. Items were selected from the state-wide assessments by using an item map which correlated each test question with a specific science standard and key idea (or ideas). A total of 38 post-assessments were returned and analyzed.

The surveys also suggest that the institute influenced student perceptions of possible careers. Greater than 50% of participants indicated that they were likely or very likely to pursue an academic major in a science related field (53%) or a math/engineering related field (63%). Further, 65% identified new career possibilities since participating in the Go Green Institute.

Analysis of the pre and post assessment data indicates that a statistically significant difference in performance was detected. Specifically, the mean raw score increased over the institute timeframe and the standard deviation around the mean decreased. These data present the possibility that the students, in aggregate, demonstrated a slightly high level of mastery when measured against the same standards pre and post, and that the group as a whole came closer to sharing a common core of understanding of the content as illustrated in the fact that there were fewer low scores on the post than on the pre-assessment and that responses, in general depicted a tighter pattern around the mean score.

We also surveyed students about their future career considerations and perceptions of the institute. Surveys results revealed that the institute offered students a broad view of science and science careers. The institute did introduce concepts in active and exciting ways which students found engaging. Based on all of the data, we contend that the Go Green Institute achieved its initial goals of (1) increasing student understanding of science and math skills and concepts related to environmental sustainability issues, and (2) Increase the scope of science career opportunities that the participants were considering.

## Introduction

Today's knowledge-based economy calls for constant technological innovation[1] to address the challenges of energy, physical infrastructure, information and communication infrastructure, environment, health, and other as yet unidentified problems.[2] Promising solutions will likely evolve from cutting edge science and engineering in areas such as nano-materials, photovoltaics, low-weight/high-capacity batteries, materials recycling, and flexible electronics. However, such next generation technologies will emerge *only if* society inspires a broader, diverse group of students to become scientists and engineers to research and develop improved products and processes. In addition, we need to prepare a technologically proficient workforce and educate a scientifically literate citizenry who make intelligent personal and public policy decisions (STEM Education Coalition[3]). The U.S. educational system is not keeping up with demand for this broad base of intellectual capital in the face of international advances in science education and competition in a global marketplace. National reports cite the continuing challenge of recruiting and retaining students who are prepared to pursue STEM degrees in higher education. For example, a recent study showed that 85% of students aged 8-17 were not interested in engineering careers.[4]

The 2007 TIMSS results reveal several disturbing middle school level trends: (1) U.S. fourth graders score statistically lower than only four countries, while our eighth graders rank statistically below nine countries, (2) U.S. gender differences are not significant at the fourth grade level, but males outperform females at the eighth grade, and (3) scores at both grade levels track ethnicity.[5] An additional challenge that emerges between these grade levels is a shift in students' perceptions of and attitudes about "science (as fun) for all" to a sense of "science for the few" who are "talented and gifted" in a narrowly and prematurely defined way. Clearly, a hole or pinch-point in the STEM pipeline exists at the middle school level.

The Go Green Institute is intended to engage students at this middle school level pinch-point. The institute was offered in the summers of 2008 and 2009. It will be offered again during the summer of 2010. In this paper, the organization of the institute is described. Samples of student projects are presented. In conclusion, the results of evaluations of the program are presented.

## Go Green Institute Organization

Up to sixty students per year are involved in exciting activities related to environmental sustainability that students do not typically experience in the school setting. Students are identified for the program by the local school districts based on student performance in math and science examinations. The institute staff consists of university faculty, two-year college instructors, middle and secondary school math and science teachers, and graduate students in education and in science and engineering. The staff has averaged eighteen members over the two years it has been offered.

The 10-day program is designed to give high performing students (who have just completed the 7$^{th}$ grade) a challenging experience that will increase their interest and ability in three core content areas: (1) Biology/Life Science, (2) Chemistry/Physical Science, and (3) Math/Engineering. Interactive content sessions, fieldtrips, and presentations by guest speakers

are included during the institute. The core content areas and the presentations focus on environmental sustainability. The capstone experience of the institute is a team research project on a topic in sustainability. Students conduct a research project, collaborating in small groups on experiments/team projects are included in the program. They create a poster presentation that is given on the final day of the institute and organized as a professional conference presentation. Table 1 illustrates the general schedule for the 10-day institute.

| **Day 1** | **Days 2-9** | **Day 10** |
|---|---|---|
| Welcome/overview | Session I | Project Work |
| Session I | Session II | Evaluation |
| Lunch | Lunch | Luncheon & Keynote Address |
| Session II | Field Trips/Speakers | Poster Session |
| Field Trips/ Speakers | Project Work | Awards Reception |

Table 1. Schedule for the Two-week Go Green Institute

Experts in each of the three core content areas facilitate the two morning sessions (I and II in Table 1) and deliver instruction as described below for each track. To maintain small groupings of students (in an effort to maximize student opportunity and learning) each content area is delivered for three days to a sub-group of 15-20 students and then rotated to the next sub-group of 15-20 students. Each sub-group of students experiences all three core content areas. Table 2 summarizes the modules for the content areas.

| Module | Biology | Chemistry | Math/Engr. |
|---|---|---|---|
| 1 | Pesticides | Micrograph length scales | Scales and measurements |
| 2 | Plant pigments | Scanning electron microscope | Mathematical models |
| 3 | Effect of salt on organisms | Energy | Statistics |
| 4 | How genetic modifications made | Energy storage | Measuring material properties |
| 5 | Enzymes | Quantitative analysis | Electricity and electronics |
| 6 | Temperature effects on organisms | Polymers | Alternative energy sources |

Table 2. Summary of Core Content Area Modules

One daily afternoon session is used for fieldtrips and guest speakers related to the content area instruction. Examples of fieldtrips from the pilot program include: a solar installation company, Broome County landfill, BU Nature Preserve and Recycling Centers, BAE Systems, and a New York State Energy Research and Development Authority "Energy Bike."

Sessions on days 2-9 and on the morning of day 10 are devoted to student team project work. The team projects serve as the capstone research experience of the Go Green Institute. Working in groups of four, students explore student-selected projects focused around the issue of environmental sustainability. Each group has a Go Green Institute staff mentor.

Projects selected by students during the summer 2008 pilot program included: How much of your favorite technology item (cell phone, computer, iPod, etc.) can be made from recycled products, or can be recycled itself? What is the most energy-efficient way to light your bedroom? "Paper vs. plastic," does it really make a difference? What is the environmental impact of your family's consumption for a week? Students will be "steered" to projects that integrate core theories from the state standards in interdisciplinary, real-world problem solving contexts that relate to STEM careers.

On the final day of the Go Green Institute, students display and present their work in the form of posters. This public presentation illustrates the findings of their team projects and gives the students a chance to further develop their communication skills. Community members and leaders, parents, school administrators, local teachers and the press are invited to this event.

**Student Projects**

The research projects are a new and exciting experience that Go Green provides students. Even though certain general questions such as those mentioned above are used to begin the projects, students are challenged to develop their own scientific hypothesis and describe an experimental approach to justify their position.

Students work on these group projects during the Project Work sessions of each day. A Go Green mentor (a faculty member, teacher, or graduate student) works with each group as a resource during this time. In addition, students conduct research each day after they leave the institute. An on-line file transfer and communication system is set-up for each project team. This is done using Blackboard$^{TM}$ course management software.

For their projects, every team conducts literature searches on-line. Some teams devise experiments, build an apparatus, and collect data. Other teams conduct surveys – for example, one group sent home a survey with e very student Go Green to determine household usage of recyclables.

Each group then creates a poster that is printed for them the night before the final poster session on the last day. A sample poster is shown in Figure 1. At the poster session, students explain their research to the invited guests.

BINGHAMTON UNIVERSITY
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# Energy Transfer in Home Heating Materials

Go Green & Big Ideas in Science Institutes 2008

## Introduction

In recent years, there has been a strong drive towards development of clean renewable energy sources for household consumption. There are many ways to heat a home but not all of them are environmentally friendly. On one hand, home heating through electric power is costly, but it does not pollute the air. Also, the kind of insulation you use in your home could make a big difference in your heating bill. The main ideas considered are aimed at fuel sources, piping, and insulation.

## Data

**Temperature change of $H_2O$ in different pipes**

| Pvc pipe | | |
|---|---|---|
| Time | Temperature in Celcius | |
| 0-2:54 | 77 | |
| 1-2:55 | 73 | |
| 2-2:56 | 71 | |
| 3-2:57 | 70 | |
| 4-2:58 | 69 | |
| 5-2:59 | 67 | |
| 6-3:00 | 66 | |
| 7-3:01 | 65 | |

*PVC and copper pipes used in experiment 2*

## Results

$2C_6H_{14(l)} + 19O_{2(g)} \rightarrow 12CO_{2(g)} + 14H_2O_{(g)}$

$q_{rxn} = -7727.4kJ$

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

$q_{rxn} = -1240.33kJ$

Heat Transfer Efficiency

EtOH (1) 2.7% (2) 5.3%

$C_6H_{14}$ (1) 3.2% (2) 5.9%

## Conclusions

Hexanes produced more heat than ethanol per amount of fuel. The simulated furnace setup demonstrates poor heat transfer efficiency. The pipes showed almost no difference in heat transfer to surroundings, but are different prices for their respective use.

## Procedure

For our first experiment, we decided to test the properties of different fuel sources. 174mL of $H_2O$ were added to a 12oz aluminum can. 1.98g and 4.04g of EtOH were allowed to burn with heat transfer through the can to water and temperature monitored. Likewise, 4.11g and 3.5g of hexanes were also used in a similar manner to determine the heat transfer efficiency from each source.

For our second experiment, 242mL of $H_2O$ at 71°C in ½" Cu pipe was allowed to cool with temperature monitored with time. Similarly, 1L of $H_2O$ at 77°C was allowed to cool with temperature monitored with time.

| Copper pipe | |
|---|---|
| Time | Temperature in Celcius |
| 0-3:29 | 71 |
| 1-3:30 | 68 |
| 2-3:31 | 66 |
| 3-3:32 | 64 |
| 4-3:33 | 62 |
| 5-3:34 | 60 |
| 6-3:35 | 59 |
| 7-3:36 | 58 |

**Heat Transfer to $H_2O$ by EtOH and $C_6H_{14}$ combustion**

| | | $T_i$ (°C) | $T_f$ (°C) |
|---|---|---|---|
| Ethanol | *Trial 1* | 21 | 23 |
| | *Trial 2* | 23.5 | 31.5 |
| Hexanes | *Trial 1* | 30 | 38 |
| | *Trial 2* | 33 | 46 |

## Discussion

In the pipe experiment, there were some mistakes in the design, like how much water was put in the tubes. In the PVC, we were able to put 1 liter in. in the copper, we were only able to put in 250 ml. Another thing to discuss is renewable fuel sources, such as solar, wind, and geothermal. These fuels are very environmentally friendly but are expensive. We did not get to cover these in the experiments.

*Ethanol and Hexanes combustion*

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(3) http://hubpages.com/hub/Best_windows_and_doors 9 Jul 2008

Figure 1. Student Work Presented at Go Green Poster Session

## Evaluations of the Program

Student achievement is show by the posters student groups generated and presented during the institute. These posters show:
*Connections*: The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena.

*Strategies*: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.
Students were able to work together effectively to generate claims based on evidence regarding current real-world problems.

We also surveyed students about their future career considerations and perceptions of the institute. Surveys results revealed that the institute offered students a broad view of science and science careers. According to one participant, "Throughout this entire Go Green Institute, the main thing I enjoyed the most were the classes of Life Science, Physical Science, and Math and Engineering. This is because, these classes taught me a wide variety of new things and concepts and I feel like I was taught in preparation for high school and college". Similarly, a second student explained, "I liked the course activities because you learned things that I don't learn in school". The institute did introduce concepts in active and exciting ways which students found engaging. One student contended, "I liked that I was pushed to learn and understand the curriculum, rather than memorizing facts to take tests". Another student summarized the previous ideas when stating, "The thing I liked best about the Go Green Institute is all of the hands on learning and experiments, because it gives you a different way of learning than you get at school, and I have learned so much just in this 2 weeks I've been here".

The surveys also suggest that the institute influenced student perceptions of possible careers. Greater than 50% of participants indicated that they were likely or very likely to pursue an academic major in a science related field (53%) or a math/engineering related field (63%). Further, 65% identified new career possibilities since participating in the Go Green Institute. Additionally, students indicated that the institute refined their initial ideas. As one student explained, "even though I have already set my main careers as I become an adult, there were a couple careers that I was not very positive about. However, because of this 'Go Green Institute', I have become sure of my career possibilities."

Based on all of the data, we contend that the Go Green Institute achieved its initial goals of (1) increasing student understanding of science and math skills and concepts related to environmental sustainability issues, and (2) Increase the scope of science career opportunities that the participants were considering.

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