AC 2011-1523: FAR-POST ASSESSMENT OF A SUSTAINABILITY ENGINEERING HIGH SCHOOL OUTREACH PROGRAM

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A general strategy for determining the effectiveness of an outreach program is to perform pre- and post-assessment of the participants. Many outreach programs include surveys of participants immediately following an event to gauge how well the program performed. Often, these surveys may only measure the participant’s level of enjoyment and not necessarily increase in content knowledge. Further, given the general aim of outreach programs is to encourage participants to explore further in the area, these post-assessment instruments provide little feedback on how well this is achieved. A systemic approach to evaluation\(^1\), including traditional outcomes tracking of what happens to participants after the program, can provide insight to true effectiveness of a program and to adaptations in the content to better meet objectives.

Post-assessments of our program indicate that participants were engaged in the activities, and were excited to learn about engineering, and the role engineers have in society\(^3\). We set out to assess the lasting impact of our outreach program on participants.\(^2\) We were curious as to what particular content areas were of most interest so as to continue developing the program content to serve students’ expectations. We were also interested in knowing whether the general focus of the program on environmental issues and sustainability was useful to the students in their day-to-day activities. Finally, since the program is intended to introduce engineering as a field of study, we wanted to know if participants became engineering students at the university level.

This paper provides some background on our outreach program, the Green Design Apprenticeship, including the overarching goals and learning objectives. The main focus of the paper is on the method and results of a far-post assessment survey completed 2-3 years after students participate in the program. The results indicate that the program content is having an impact on students’ daily activities, and is helping students make decisions about fields of study. We also provide some strategies for initiating far-post assessment in outreach programs.

The Green Design Apprenticeship

The Green Design Apprenticeship, offered since 2004 by the Green Design Institute at Carnegie Mellon University, is an outreach program for gifted and talented high school students interested in learning about academic and career options in engineering, especially options related to environmental and sustainability issues. The Green Design Apprenticeship is one of several apprenticeship opportunities offered through the Gifted and Talented Program of the Allegheny Intermediate Unit (AIU) in Southwestern Pennsylvania. The AIU supports multiple school districts in the area with special education needs that individual schools cannot support themselves. The intent of the AIU Apprenticeship Program is to help guide students’ educational and career choices by exposing them to people and organizations related to careers that interest them. For example, students can apply to apprenticeships in broadcast journalism, musical conducting, nursing, and zoology to name a few. Each spring, students in ninth through eleventh grades can apply to participate in one of 30 to 35 apprenticeships that will be held during the
following school year. Only two of the apprenticeship options specifically focus on engineering. The AIU markets the Apprenticeship program to teachers and schools, accepts and evaluates applications, and selects the final cohort of students for each apprenticeship.

Students who participate in the Green Design Apprenticeship excel at science and math. In pre-assessments, students often note that they have been told “to consider engineering” as a field of study, but do not have information on the field. They are interested in learning more about the opportunities of the profession. Many, but not all, also have an interest in environmental issues. Each cohort has included approximately 20 participants mainly from higher achieving, suburban school districts.

A main objective of the program is to introduce students to the intersection of engineering decision-making with environmental and social issues. The content of the program frames activities around the theme of “life cycle thinking” and emphasizes the trade-offs in materials and energy inputs and environmental impacts across life cycle stages. The program topics include product life cycles, measuring life cycle impacts, energy generation and consumption, and the resource demands of built infrastructure. Current research work of faculty and graduate students affiliated with the Department of Civil and Environmental Engineering and the Department of Engineering and Public Policy are highlighted throughout the program. Although the organizers of the program are limited to these two engineering areas, we focus on the role engineering in general has on society. We emphasize at the outset of the program that all fields of engineering have impacts on society and the environment. We encourage students to investigate the various fields of engineering to discover which one appeals to them the most, then seek out ways to include their interests in environmental and social issues in that field.

Research Questions

Post-assessment at the end of the program indicates that students are generally satisfied with the program. The content has been engaging, environmental issues are now something they consider in decisions, and they have a better idea of whether engineering might be right for them as a field of study. But, how lasting an impact did our program have on participants?

To answer this question, we performed two far-post assessment surveys of participants 2-3 years after the program end. We were curious to answer three questions:

*What topics resonate with students after the program completion?* As engineering, environmental, and social issues come in and out of importance, we adapt the content of the program slightly. Some activities and topics have stayed in the program year-after-year. We wanted to garner student feedback on the topics to determine which concepts and skills remained useful to students, both academically and socially.

*Do the participants use the material in their day-to-day lives?* To explain some of the environmental and sustainability concepts of the program we include examples that involve
decisions students would make in their daily lives. For example, as a precursor to discussing impacts of electricity generation, we have students calculate the electricity consumption in their own bedroom for a year. We wanted to learn if these concepts were still being used by students and in what capacity.

*Does our program draw students into STEM fields, and in particular engineering with an environmental/sustainability focus?* The overarching objective in exposing students to the intersection of engineering decision-making with environmental and social issues is to get them to study engineering with this perspective. We know students come in curious about engineering as a possible field, but we wanted to learn from both a positive and negative perspective how well we were doing in this regard. Two students from the program enrolled in engineering at our institution, but we were curious what the other students had decided to pursue and whether participating in our program was part of that decision.

Methodology

Past participants from each program year from 2004 through 2008 were included in the far-post assessment. Participants for each year included high school students in their sophomore, junior, or senior year of high school. The surveys were administered in Fall 2007 to students in the program in 2004, 2005, and 2006, and in Fall 2010 for students in the program in 2007 and 2008. This timing allowed a majority of students in each cohort to enter college or to be at a point where area of study was being decided.

For the 2007 survey, students were mailed a letter with a link to the survey on-line, as well as a paper version with reply envelope. Reminder postcards were sent to students one month after the initial mailing, and a final request via email one month later. For the 2010 survey, only email requests were sent out to complete the survey on-line. The instrument is provided at the end of the paper. Question 2 regarding the topics covered changed according to the content included each program year. A total of 34 students responded to the surveys. Response rates (Table 1) for the 2007 survey were between 40% - 60% for each cohort, while for the 2010 emailed survey were around 25% for each group. Eight of the 34 respondents were still in high school at the time the survey was administered, all in the 2007 survey. All other respondents were currently enrolled in a university program. We did not survey a control group of students who did not participate in the outreach program.
Table 1. Cohort size and response rates for the surveys. Students from the program in 2004-2006 were surveyed in 2007. Students from the program in 2007-2008 were surveyed in 2010.

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort Size</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Responses (N)</td>
<td>6</td>
<td>9</td>
<td>10</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Response Rate</td>
<td>40%</td>
<td>56%</td>
<td>63%</td>
<td>25%</td>
<td>22%</td>
</tr>
</tbody>
</table>

Results

*What topics resonate with students after the program completion?* Since this program was the first encounter for many of the students with topics related to sustainability and green design, we were interested in knowing which topics resonated with the students after the program was complete. Mentions of different topics are indicated in Table 2. Students mentioned multiple topics, and 2 students indicated “all.” The results were not overly surprising to us, given the activities for the particular concepts. The green buildings topic, for example, involves a tour of on-campus LEED-certified buildings and construction projects, including the Intelligent Workplace a living laboratory of current green building design research in the Department of Architecture. Student responses specifically mention the tour and recall visiting one or two of the spaces. Life cycle thinking involves an activity where students are introduced to the idea of supply chains and the material and energy resources consumed for a common product. This has always been the initial concept of the program each year, and we refer to the activity and concepts throughout the program. Brownfields are mentioned by the most students from 2004, however the person leading that area was no longer involved with the program in subsequent years and thus the material was replaced with other extended content in life cycles and energy issues.
Table 2. Topic areas that respondents indicated continued to resonate with them after the program completion. NA - topic was not covered that program year. Multiple selections allowed.

<table>
<thead>
<tr>
<th>Topic</th>
<th>2004 (N=6)</th>
<th>2005 (N=9)</th>
<th>2006 (N=10)</th>
<th>2007 (N=5)</th>
<th>2008 (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life cycle thinking and life cycle assessment tool</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Energy issues</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Green buildings</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Water issues</td>
<td>NA</td>
<td>2</td>
<td>NA</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Brownfields</td>
<td>3</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Student responses for why these concepts still resonate mention the use of the ideas during daily decisions, in classes (both in high school and in college), and in current events. Students also mention sharing the ideas with others. Several students mentioned using the concepts as a starting point for school or home projects. As an example, one respondent commented:

*I would say the Green buildings and the sustainability still resonate with me the most, though a lot of the topics we studied have all contributed to my, shall we say, environmental outlook of the world. One of the things that have come out of this apprenticeship is a new thing to do while on college visits: count the number of green buildings and see how environmentally aware the campus is, which, I must add, has transformed into a criterion for me.*

Do the participants use the material in their day-to-day lives? Similar to the responses for the content that remains with students, participants indicate that the concepts they learned are used now in other areas of their lives as shown in Table 3. Most students from each year note that the concepts are used when making daily decisions. Students specifically note making efforts to recycle and conserve, using the information in purchase decisions, and talking to others about the general idea of considering life cycle impacts. In their coursework, students indicate that the knowledge of specific topics, such as renewable energy sources, has been a useful starting point for research projects. Two students were also appreciative for the exposure to modeling problems and research methods. They found the prior experience useful when approaching unstructured problems in courses at the university level.
Table 3. Areas in their daily lives where students use the concepts learned in the program. Multiple selections allowed.

<table>
<thead>
<tr>
<th>Area</th>
<th>2004 (N=6)</th>
<th>2005 (N=9)</th>
<th>2006 (N=10)</th>
<th>2007 (N=5)</th>
<th>2008 (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily decisions</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Classwork</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Extracurricular activities and work</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not used</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The student comments of course fall across the spectrum of impact. Some are very general and vague:

*I do find that I think about the effects on nature now and consider more efficient ways of performing things.*

Others note a certain instances where the general knowledge has proven useful:

*Well, at the end of last year I did a presentation on alternative fuel sources for my chemistry class, and while we never explicitly talked about the alternative fuels in a meeting, I went through my materials and was able to come up with some data that was really useful for the presentation. Other than that, my application of the concepts has been more passive, more like- "oh look, that's a green building" or "look mom, that's a hybrid car. Do you know exactly how those work? I do..." I showed a teacher the Economic Input Output Life Cycle Assessment website and it really helped her future cities team when they had to write about the environmental implications of their futuristic city. Mainly, I've just been trying to stay aware of the environmental issues.*

And, finally others provide specific behavioral changes and purchase decisions as a result of participating:

*I can honestly say that I apply what I learned at the apprenticeship every day. I always turn off the electricity when I am not using it and always wash my clothes in cold water. I now buy most of my clothes used. I also traded in my 1980 International Harvester Scout for a Ford Ranger. This may sound corny/unbelievable but this apprenticeship has totally changed my lifestyle.*

*Does our program draw students into STEM fields, and in particular engineering with an environmental/sustainability focus? The final area of interest for the far-post assessment was*
whether or not the students are drawn into engineering fields, and/or fields with environmental 
and sustainability focus, as that is an overarching goal of the program. As noted, the students are 
bright students who excel at science and math, and often have been told to consider engineering 
for study. Our pre-assessment surveys indicate that students have general notions of engineering, 
but a primary reason for attending the program is to learn what engineers do and whether it is a 
field that would interest them in the long run. Since the program is housed in the Department of 
Civil and Environmental Engineering, many students enter with those two fields of study in 
mind. However, we make a point to emphasize that green design issues pervade all fields of 
engineering, and that students should investigate all areas of engineering to see which one 
appeals to them the most and then find a way to bring any concerns for the environment into that 
particular field.

Table 4 shows student responses of their current or intended field of study. Students mention 
several different fields of engineering: aerospace, civil, environmental, mechanical, biomedical, 
 electrical, computer, chemical, and engineering science. Two students from the program are now 
pursuing civil engineering undergraduate degrees at Carnegie Mellon University. Two indicate 
studying or intend to study architecture after the discussions of green buildings and the role 
architects play in design. Environmental science is mentioned by three students. Fields of study 
outside engineering include: pharmacy, math, chemistry and psychology, computer science, 
geoscience, pre-law, food science, and biology.

Table 4. Current or intended fields of study for program participants. Single selection allowed 
between engineering and not engineering. If student indicated an environmental focus, 
regardless of entry into engineering, it is noted in the last row.

<table>
<thead>
<tr>
<th>Field of Study</th>
<th>2004 (N=6)</th>
<th>2005 (N=9)</th>
<th>2006 (N=10)</th>
<th>2007 (N=5)</th>
<th>2008 (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Not engineering</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Environmental</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Students were asked if participating in the Green Design Apprenticeship have any influence on 
what career path the student was considering. We classify these responses as the program 
influencing the student towards engineering, away from engineering, towards environmental 
issues, or neutral (meaning other factors led to a student’s choice of field of study). Results are 
given in Table 5. These results generally follow the pattern for the intended field of study as the 
program served as an entry point for learning about engineering disciplines. Of the nine neutral 
respondents, two students indicated that it confirmed their choice of engineering (one is in an 
aerospace program, the other in electrical and computer engineering). Several of the other
neutral respondents recalled the program being a worthwhile experience even though they knew what field of study outside engineering they were interested in, or mentioned that the program did direct them toward environmentally focused studies that was not an initial consideration.

Table 5. Influence of the program on participants’ decision to pursue a selected field of study. Single selection among ‘toward engineering,’ ‘away from engineering’ or ‘neutral.’ If student indicated an environmental focus, regardless of entry into engineering, it is noted in the last row. One student in 2006 did not respond.

<table>
<thead>
<tr>
<th>Influence</th>
<th>2004 (N=6)</th>
<th>2005 (N=9)</th>
<th>2006 (N=10)</th>
<th>2007 (N=5)</th>
<th>2008 (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toward engineering</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Away from engineering</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Neutral</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Toward environmental issues</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Student comments provide insight on how the program aided their decisions. For some, the program helped decide between engineering and other fields of study, or clarify different areas:

Before the Green Design Apprenticeship, I wanted to pursue an education in environmental/biological science. The apprenticeship helped me to realize the differences between engineering and science majors, and the different roles they play in the working world. (Student entered engineering program.)

I never thought that I wanted to be an engineer; both my parents are civil engineers, and what they talked about doing at work convinced me that engineering wasn't for me. At the Green Design Apprenticeship, I realized that engineering is not simply retaining walls, pipes, and stabilization, but it is problem solving, which is something that I thoroughly enjoy. Basically, the Apprenticeship was a positive influence on choosing to pursue a degree in engineering.

For those students who are pursuing engineering degrees, comments indicate that the program helped them select a particular engineering field, or eliminate certain fields:

It made me realize the need for green design in all types of engineering although I am not looking at civil or environmental engineering. It made me realize those majors are not quite right for me.
This apprenticeship is definitely why I am an engineer and specifically after speaking with other graduates at Carnegie Mellon I chose Biomedical Engineering and it couldn't be a better fit.

For students who elected not to enter engineering, the program helped as well. Some realized that engineering held no interest, but others realized that they were more drawn to the environmental issues and wanted to investigate those problems though other majors.

Mostly, participating in the [apprenticeship] did just what it was supposed to; show me what engineers do. However, in my case, this showed me that engineering was not the field I should go into and that I was not as interested in it as I thought. (Student entered Mathematics/Philosophy.)

Absolutely. The apprenticeship has completely changed my outlook on the environment. Before the apprenticeship, I knew the basics: you need to recycle, buildings were being built with gardens on the roof, you need alternative fuel sources, but the apprenticeship put everything into perspective for me.... Honestly, if it hadn't been for the apprenticeship, I wouldn't even be thinking about a career having to do with the environment. (Student entered pre-law, considering environmental law.)

And, of course, comments let us know that our program is having an impact, but are only one small part of a student’s exposure to the field.

At the time of the apprenticeship I wanted to be an engineer; but I don't anymore. I do not blame the apprenticeship for the change in my decision, instead I blame my sorry excuse for a physics teacher.

Insights to Far-Post Assessment

The process of administering the far-post assessment was a learning experience itself. We have adapted some of our other procedures related to the program as a result. We offer this list of strategies for others who may be interested in adding far-post assessment to their programs.

Align all assessment instruments. We had been administering pre- and post-assessment surveys to students each year. However, we have added questions specifically about interest in engineering fields to the pre-assessment survey to be able to compare with the far-post-assessment information on current field of study.

Tell students that you will be contact them again. In the 2007 survey responses, one student from 2nd year of the program wrote:
Why didn't I get this [the far-post assessment survey] sooner? I am not annoyed, just curious why you waited 2 years.

On the post-assessment survey immediately following the program, we now tell students that we are curious about the impact the program had on their decisions to pursue different fields of study and that we will likely be contacting them in the future.

Request updated contact information from participants at the end of the program. A major difficulty in far-post assessment is likely to be response rate. Our program runs throughout the academic year, and even during that time frame, it was surprising to learn how many students had new emails and that a few had moved houses. We ask students at the end of the program for mailing address, and current email address for themselves and their parents.

Sometimes paper is better. We were surprised at the low response rate for the Fall 2010 survey that was done only via email. Emails were sent to both students and parents, with parents asked to please forward the message to their child. We intend to follow up with mailed requests to hopefully gather more responses.

Time requests for information with the students’ new calendars. We asked current undergraduate students about how to best notify past participants who would now be in college. Although they were skeptical of the mailed requests, all agreed on timing the mailing to arrive at home addresses in late November when students were likely to be home from college. Similarly, the postcard reminders were mailed in mid-December at the end of term.

Conclusions

The far-post-assessment results have been helpful in evaluating the content and focus of the program. We have retained the activities related to life cycle thinking and life cycle assessment, and we have expanded the green building tour, but we have decreased emphasis on sustainability indicators separately. We continue to provide strategies for how the concepts of life cycle thinking can be applied to their everyday lives. Since students are using the content in school projects (in high school), we are providing the students with valid resources to consult once the program is over. We continue to stress the wide range of engineering disciplines available, and highlight ways environmental and sustainability concepts apply to each. Due to the interest in engineering programs, we discuss different programs of study (e.g., typical civil and mechanical engineering curricula) and the basic math and science courses that are usually required. Yet, at the same time, we also emphasize the need for students in science and social science areas with technical skills. Our program serves gifted, suburban students who are likely pre-disposed toward engineering (and perhaps also environmental) fields, yet the results indicate that our program fills a void in engineering awareness, and our results show the program does inspire
some students to pursue engineering. We look forward to continuing this assessment technique to further develop our program.

As much as the results have been helpful to us in refining the curriculum and materials presented within our own program, we share the experience and results as a small, first attempt at far-post assessment for a single outreach program that others could learn from. The K-12 informal STEM education community needs to do a better job evaluating the honest, long range impact of a STEM intervention, especially as funding agencies demand evidence that money is being used effectively. Conducting a far-post assessment requires additional effort, but since these efforts often parallel tasks performed at the beginning of a program, building the assessment into a program does not need to be burdensome and with careful planning can provide insight into how to develop the program for future students.

Bibliography


Survey Instrument

1. What is "green design" and/or "sustainability"? How does it relate to engineering?

2. Below are the topics covered on the various days of the program. Which topic or activity still resonates with you? Why? Life cycle thinking, energy and electricity, transportation counting, green buildings, sustainability indicators, brownfields.

3. What other topics or activities do you wish we included or wish we had covered more deeply?

4. Where are you now?
   __Still in high school
   __Enrolled in college/university
   __Working
   Other (please describe)

5. What field of study or work are you currently pursuing or considering?
   __ Engineering or engineering science
   __ Not engineering
   Specify field (e.g., civil engineering, or economics, or sales)

5. Did participating in the Green Design Apprenticeship have any influence on what you decided (are deciding) to pursue? Influence can be positive or negative with regard to the program

6. Do you (have you) applied any of the concepts the from Green Design Apprenticeship in your studies, work, everyday life?