# AC 2009-986: A COLLABORATIVE "HOW TO": MAKING ENGINEERING INTERESTING TO STUDENTS IN MIDDLE AND HIGH SCHOOL

**Terence Fagan, Central Piedmont Community College**

Dr. Fagan earned a Ph.D. in Mechanical Engineering from UNC Charlotte and is a CPCC 2008-2009 College Fellows recipient, receiving funding to conduct LCA case studies on sustainable livable habitat; create a sustainable manufacturing module; and publish and present his findings. Dr. Fagan team-taught an interdisciplinary (civil and mechanical engineering and architecture students) sustainable design studio course at UNC Charlotte in 2008. Dr. Fagan currently serves on a Habitat for Humanity committee dedicated to "greening" their products and processes. In addition, he serves on the Greater Charlotte Region BioFuels Center conducting Life Cycle Assessments on BioFuel production.

# A Collaborative "How To": Making Engineering Interesting to Middle and High School Students


## Abstract:

The U.S. has seen a recent shortage of engineers and the outlook of those interested in the field looks bleak. The shortage is due in part to the baby-boomer generation of manufacturing and engineering workers retiring. However, the stigma surrounding manufacturing and engineering as "boring" or "too difficult" cannot be ignored. Now is the time for those in industry and academia to find opportunities that change this stigma and offer a more positive outlook on the engineering industry. This paper addresses a service learning project that involved first year Mechanical Engineering Technology and second year Graphic Design students collaboratively working on "How To" delivery systems that would engage middle and high school students. Some of the projects included comic books on "How to Modify an Xbox 360" and videos and pamphlets on "How To Build a Car Stereo," which encourage them to work with their hands. The novelty of the delivery systems, coupled with more age-appropriate and interesting projects, introduce middle and high school students to the exciting world of engineering.


## Introduction

Engineering and technical fields are growing due to the baby boomer generation retiring and an increased demand for technicians, scientist, and engineers. "The number of U.S. jobs requiring science and engineering training is expected to grow for the foreseeable future. Some observers say that not enough new engineers are graduating from U.S. schools to fill the positions that will open up over time."[9] To combat this need, engineering education needs to be infused not only in higher academia but at the K-12 curriculum.

Recent attempts have been made to introduce engineering principles into the K-12 curriculum. This is mainly due to society needing engineers for economic progress and is coupled with a lack of interest in pathways for engineering education. It is up to the K-12 engineering educator to focus the skill sets needed to succeed in this arena using help from higher academic institutions. These educators need to familiarize themselves with a variety of pedagogical practices, including technology education[1] and being open to creative solutions[7].

K-12 engineering education plays a large part in educating the future generations of engineers. Many organizations and higher academic institutions have developed or are developing curriculum to combat the loss of engineering emphasis in K-12 educational systems. Studies continue to be conducted that examine not only the mission and goals of engineering, but the use of engineering principles[2] in the classroom. In addition, states, noticing the decline of students in the engineering field, are beginning to address the concern for K-12 engineering education. One particular example of this undertaking includes the state of New Jersey's efforts in curriculum development and professional development for teachers as a reward for introducing engineering to K-12 students. The Stevens' Institute of Technology focuses their efforts on "Core

Curriculum Content Standards to ensure that all students, elementary through high school, experience engineering as an integral component of their education, not merely as an elective course or extracurricular activity."[3] This effort enhances the dissemination and quality of engineering throughout the K-12 educational system.

Efforts of Engineering Research Centers (ERC) are focusing on outreach programs to allow 6-12 Science, Technology, Engineering and Mathematics (STEM) teachers to explore research opportunities at university labs. The teachers bring their research lab experience into the K-12 engineering and science labs, benefiting both students and teachers.[4]

In addition, on a curriculum level there have been some creative ways to introduce engineering to K-12 students, including the use of candy. This innovative approach focuses on math skills where "upon the completion of the lesson activities, the students were able to differentiate between mass and volume as well as calculate density."[6] Another example of creative learning can be seen in the Adaptive WATER Laboratory design built by five Rice University seniors. The laboratory was used to implement educational outreach. "The aim of this outreach was less to demonstrate the Lab itself, and more to generate interest among these students because of the concerning numbers of minorities entering science, technology, engineering and math (STEM) fields."[5]

The premise of the "How To" project was to utilize service learning in higher academia to support K-12 engineering education. The idea for service learning helps college students understand real word issues and utilize their specific skill set, which adds value to a broader picture. As is pointed out by the Learn and Serve Clearinghouse, "Service-learning combines service objectives with learning objectives with the intent that the activity changes both the recipient and the provider of the service. This is accomplished by combining service tasks with structured opportunities that link the task to self-reflection, self-discovery, and the acquisition and comprehension of values, skills, and knowledge content."[10] By incorporating service learning into this freshman engineering course, there were three main goals; collaborate with students of different study areas in order to gain communication skills necessary in the engineering workforce, apply engineering ideas to social issues that affect local community schools and students in k-12, and increase awareness and change stigma about the engineering industry.

**Background**

This paper focuses on a service learning component that attracts K-12 students to the engineering discipline through a collaborative creative semester project between Engineering Technology (ET) and Graphic Design (GD) students at Central Piedmont Community College (CPCC) in Charlotte, NC. The "How To" project, as it was dubbed, involved Kenn Compton at CPCC, Dan Colhan at CPCC, Dimeji Onafuwa at CPCC, Gerald Holt at Olympic High School, John Colwell at Shelby High School and Terence J Fagan at CPCC. The "How To" project encompassed 30% of the ET students' grade, replacing a semester long five page research paper. By the end of the semester, 9 of 12 ET student projects were submitted, paralleling the 9 data points in the results section.

The project was inspired by Saul Griffith, Joost Bonsen and Nick Dragotta at HowToons[7] a website dedicated to peaking the interest of children and teenagers through a novel delivery system - the comic book/graphic novel. The technique is simple; each short story teaches fundamental building techniques. Some of the builds are quite challenging to middle school children. As with the Howtoon's website, the focus here is more on building the projects and less on the mathematics or engineering behind the projects. The approach is to attract K-12 students using a familiar medium as an entry point to the world of engineering and manufacturing. In addition, the projects emphasize learning through working with one's hands. Harvard graduate Calvin Woodward said it best: "Engineering students will be able to here acquire dexterity in the use of` tools, which, though slight, will be a great value to them, in the subsequent work of their profession (i.e., this experience will make them better judges of workmanship)" qtd. in Sanders[2].

The project encompasses three important areas: creativity in Engineering Technology, Service Learning/Outreach K-12, and multi-area collaboration. The paper highlights efforts on the Service Learning/Outreach aspects of the project obtaining data from the ET students. Since this was a collaborative project with an emphasis on teamwork, the instructors wanted each of the ET and GD students to be involved from the start.

It was understood by all participants in the project that one main goal was to change the stigma surrounding manufacturing and engineering and find a way to increase interesting in these fields. The focus was on the deliverable material, one that would get the K-12 students to think about engineering as a means to create, solve problems and improve the world around them. In the end, the project should provide quality material to K-12 engineering educators to promote STEM.

**Methods, Procedures**

The instructors generated a workable plan to get the two classes of ET and GD students together multiple times. In addition, to jumpstart the project, the classes used data offered from a survey given to the high school students. The plan consisted of high school student surveys (Appendix 1) distribution and analysis, writing a design brief, peer/teacher critiques, presentation and reflection questions.

The roles were chosen to align each student to his/her respected curriculum. The ET students were in charge of the material content and the GD students were in charge of the delivery system, whether it was a graphic novel, poster, manual etc. The ET content consisted of a bill of materials, a process plan, description of each process and the target audience. The instructors wanted to make sure the students were working collaboratively from the onset of the project to create integrated results while simulating real world joint ventures.

Below is the outline set in chronological order detailing the ET students' project action plan starting on November 3rd and ending December 8th, 2008.

On Nov. 3rd, the class assignment was to analyze the surveys looking for trends in high school students' interests and activities. From the high school students' background, the ET students generated preliminary project ideas. The interests were wide and varied, ranging from playing football to hanging out with friends to playing outside to music. The most popular interests were sports, video games and music. The most intriguing survey, written in pink by a 16 year old female emphasizing her want to provide food for starving people using engineering skill set, is shown in figure 1. When asked what they would like to build, the answers were just as varied ranging from a beach house to a time machine, to a gigantic bubble gum machine, to a hover board.

The ET students were instructed to couple their particular interests with the HS student(s)' interests, meanwhile asking themselves, "How did I become interested in engineering and technology?" The intent of merging their interests was designed to keep the ET students engaged throughout the entire process. Below is a list of the student projects that took into consideration the HS surveys:

- How to upgrade your Xbox
- How to upgrade the electronics on your guitar
- How to build a potato gun
- How to install a car stereo
- How to string your electric guitar

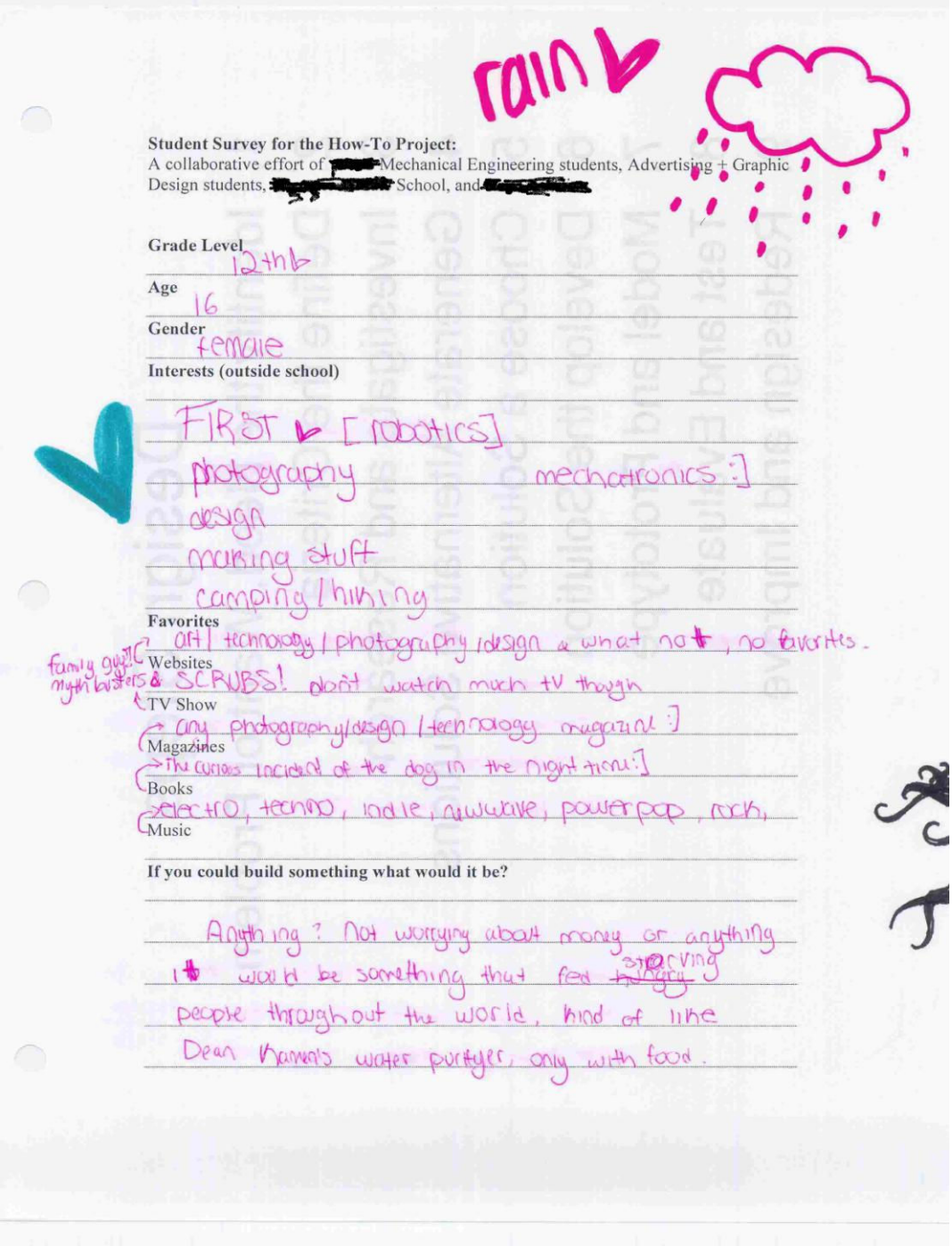


Figure 1.) Represents one of the surveys that were analyzed.

It was decided each of the classes had to meet outside of their original schedule only once. Therefore, the classes met twice throughout the project. For the first meeting, the GD students met the ET students during the Manufacturing class time on November 10th.

During the class, the amount of information that can be effectively communicated was the topic

of discussion. The ET students wanted to include a lot more information than the GD students did. This caused some tension and ultimately scaled back many of the projects. The project on "How to Build a Computer" got scaled back to "How to Upgrade Your Computer." The project "How to Install a Car Stereo" was decided to focus on an entirely different topic and age group altogether and focused their efforts on how to build a kite. This new project targeted middle school children.

At this time, certain objectives were met: introduce each of the students to one another, randomly pick the team consisting of two GD students and one ET student, and each team formulating a design brief using the following parameters.

- Background Information on the high school students.
- Your target audience - use analysis from the surveys.
- Project Objectives - what do we want to accomplish?
- Message - what do we want the audience to understand (single message)?
- Deliverables - what would we use to give the message? (comic book, video, pamphlet, etc..)
- Timeline/Milestones - Due Dates. How many rounds of revisions are expected?
- Budget Constraints - Maximum amount to be spent on development. In addition, since there was no budget for media, the projects were to be soft copy only.

The second scheduled meeting took place on Nov. 20th at the GD lab. The groups had four major goals: critique their own drafts, create a more refined project, informally present their work, and obtain feedback from other students in the class. This peer review technique is used heavily in the Graphics program but it was new to the ET students. The evaluation seemed to be very helpful to not only the students but it helped the instructors understand the choices in the project. When the students critiqued and questioned each other, they appeared to be more relaxed and open to suggestion than if an instructor was asking them. In addition, this process updated the students and the instructors and allowed the instructors to give feedback as well.

On Dec. 8$^{th}$, the ET students presented their final projects to the manufacturing class. The presentation concentrated on the lessons learned. In addition, the students completed reflection questions and peer evaluations. "The reflection referred to in the definition of service-learning is not a fuzzy activity designed to make you feel better. It is a vital and rigorous component of the learning process."[8]

Due to time constraints and other commitments, as of this writing, the student projects are being critiqued by the high school teachers and their students. To deliver the projects to the high school, a website containing all the projects was created. In addition, the high school students will fill out another survey focusing on the validity of these projects.

## Results

The results section has two subsections. The first section labeled Student Final Projects presents two of the final projects chosen by the length, quality content, and focus. The second section labeled Reflection Questions and Statistical Results presents statistics on common student thoughts on service learning from the reflection questions in A3.

## Students Final Project

Figure 1 and 2 shows a two sided poster instructing the audience on how to update the hard drive of an Xbox 360. The poster's intent was to pertain to female and male high school students alike. Figure 1 shows the front side of the poster showing a girl cracking into her Xbox using a screw driver. This shows that young women can be just as techie as guys. In addition, the picture of the girl is to attract a young male's attention. Figure 2 steps the audience through a "How To" process focusing on upgrading the hard drive of the Xbox 360. Furthermore, from an entrepreneur's point of view, this "Do It Yourself" (DYI) process of upgrading saves the participant a minimum of $150. This project's audience is high school students interested in either gaming or entrepreneurship.

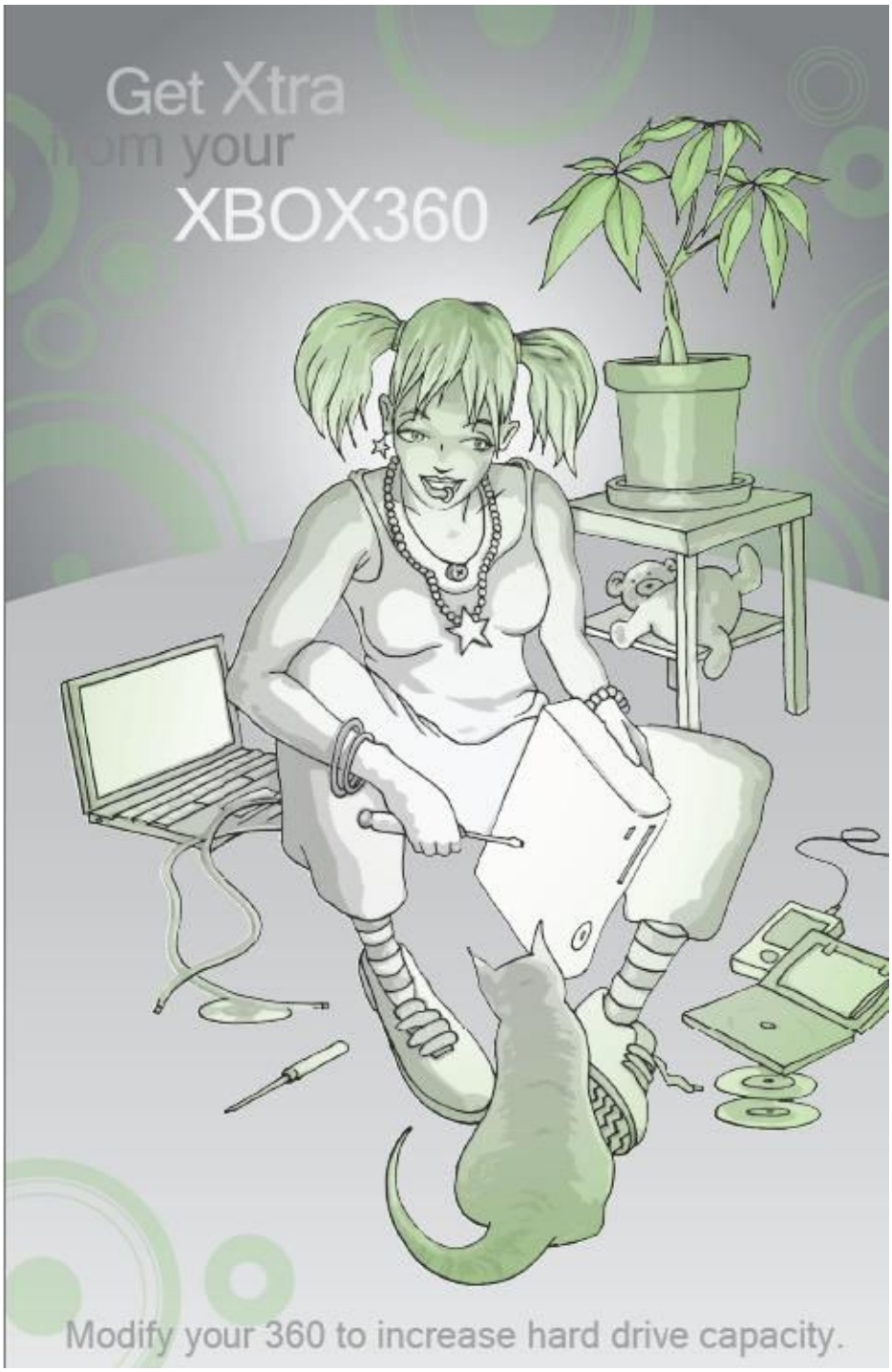


Figure 1.) Shows the front side of the poster illustrating a young female upgrading her Xbox 360.

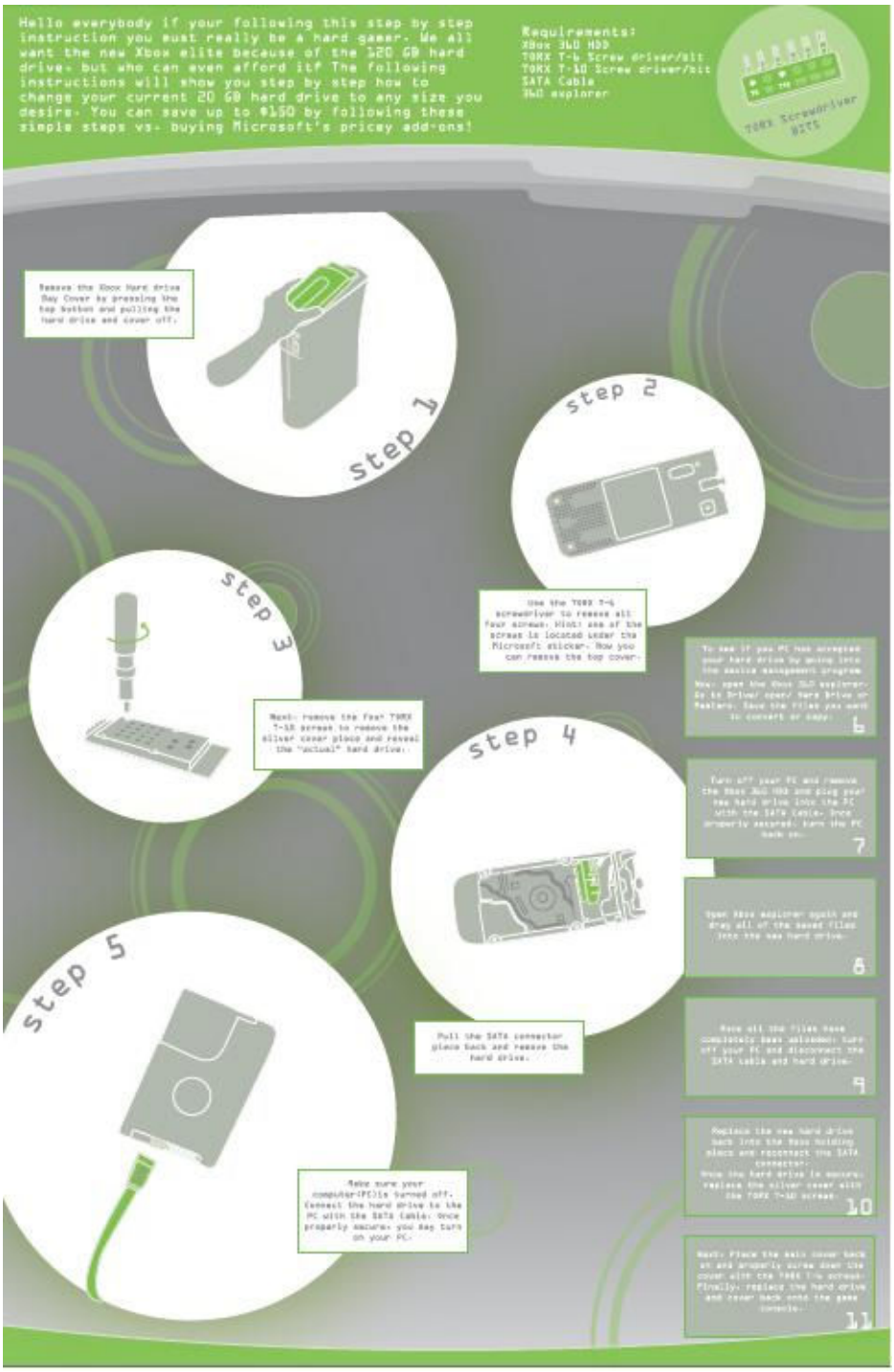


Figure 2.) Shows the back of the poster instructing the audience on the process to upgrade the hard drive of an Xbox 360.

The poster illustrated in Figure 3 instructs a middle school student on how to build a kite out of sticks, a plastic bag and string. This multi-gender poster not only focuses on building an item, but incentivizing children to go play outside. The project demonstrates a DYI mentality that

focuses on creating your own toys with recycled and ubiquitous material. This project requires very little skill but emphasizes a Robinson Crusoe mentality of inventiveness[11].

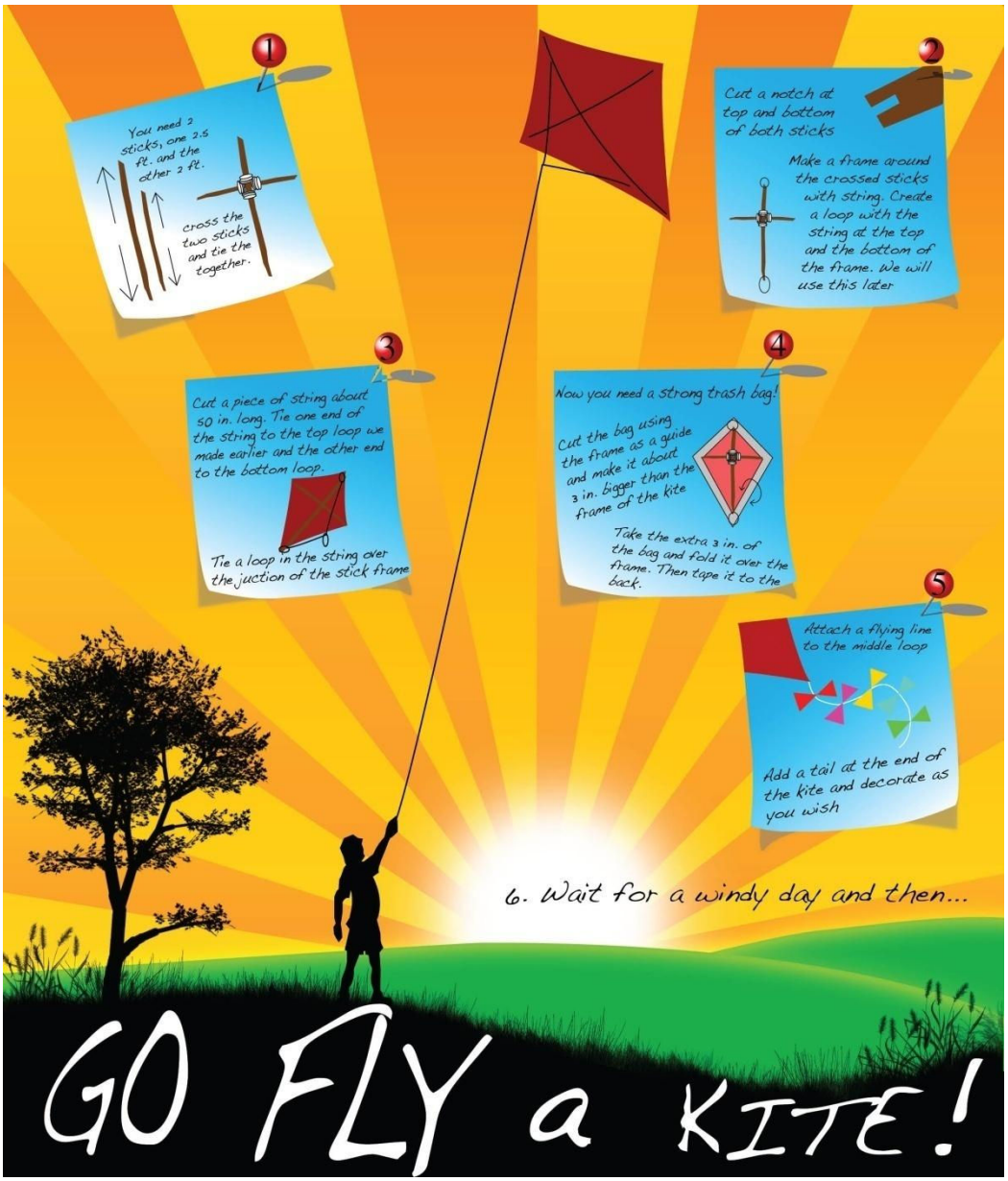


Figure 3.) Shows a poster illustrating toy building with recycled and ubiquitous material, which incentives children to go and play outside

**Reflection Questions and Statistical Results**

Outlined in this section are the service-learning reflection questions and student answers. The questions were designed to allow the students to analyze their work on the project while focusing on the larger picture: "How can engineers work with other people to benefit society?"

The questions were given on the last day of the class after their presentations. Figures 4 -7 graphically highlights recurring themes throughout the students' answers.

Question 1: How can [engineers] work with other citizens together to solve problems? Why should they?

Question 1 focused their attention on how engineers work with people from different backgrounds to solve problems. Figure 4 is organized where each bar represents certain engineers' attributes. The raw data is in A3. The attributes include: communication (3 students), ideas (1), interconnectivity (1), understanding problems (2), open minds (1) and not sure (1). Note the not sure group is from the author's point of view of the student's answer.

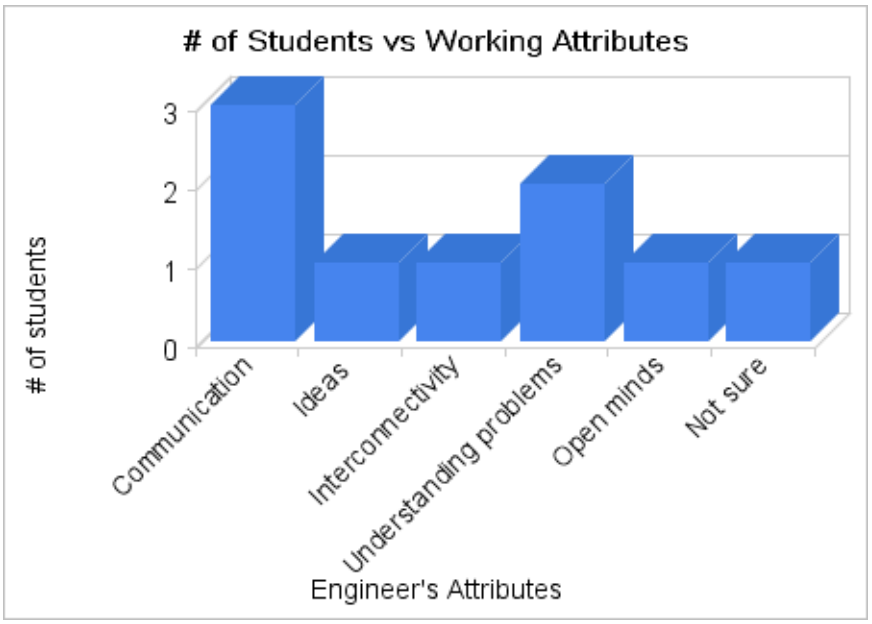


Figure 4.) Illustrates the grouping of the students answering the engineering attributes of how can engineers work with other citizens together to solve problems?

Question 2: Think of a [engineering] principle that can be applied to help understand a social problem. How does your thought process [as an engineer] affect the way you view social issues? Can social issues affect the way you do science?

Question 2 focused their attention on how engineering principles can be applied to social issues. No engineering principles of social problems were given as examples. The answers were divided into two categories - engineering principles and social problems. The reason for the distinction was due to the fact that there were coupled themes throughout the data.

Figure 5 is organized where each bar represents certain engineering principles collected from student answers. The raw data is in A3. The engineering principles include: general methods (3 students), process plan (1 student), force multiplies (1 student) and not sure (4 students). Note

the not sure group is from the author's point of view of the student's answer.

**Engineering Principles**

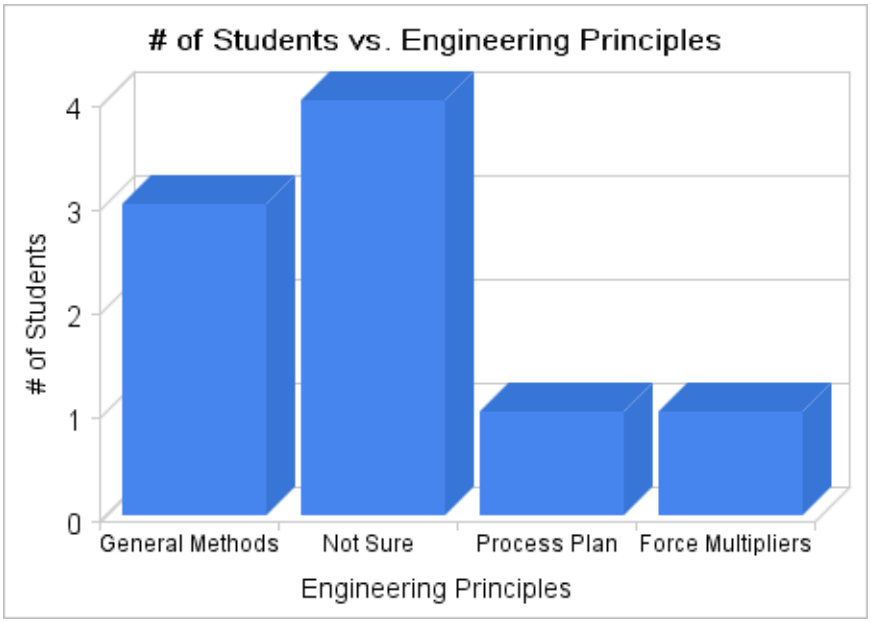


Figure 5.) Illustrates the students' answers focusing on applying engineering principles to question #2.

**Social Problem**

Figure 6 is organized where each bar represents certain social issues collected from student answers. The raw data is in A3. The social issues include: general (4 students), sustainability (3 students), and not sure (2 students). Note the not sure group is from the author's point of view of the student's answer. Although the majority of the students were very general in answering the questions, many of them mentioned the need for communication.

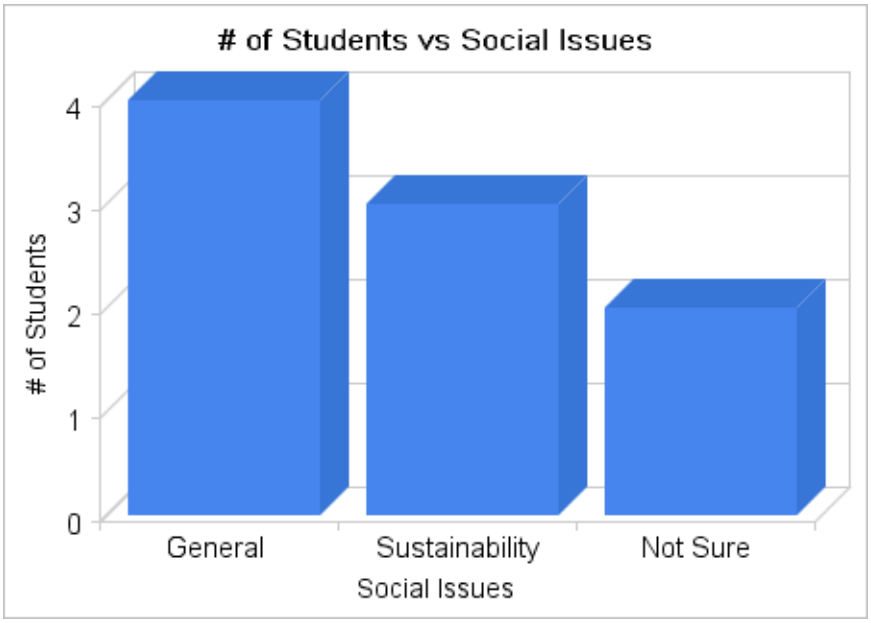


Figure 6.) Illustrates the students' answers focusing on social issues to question #2.

Question 3: What personal qualities (e.g. leadership, communication skills, compassion, etc.) have you developed through service-learning? How will these qualities help you in the future?

Figure 7 organizes the development of personal qualities the students developed throughout the "How To" project. The raw data is in A3. The personal qualities include: leadership (1 student), communication (4 students), holistic understanding (2 students) and other (1 student).

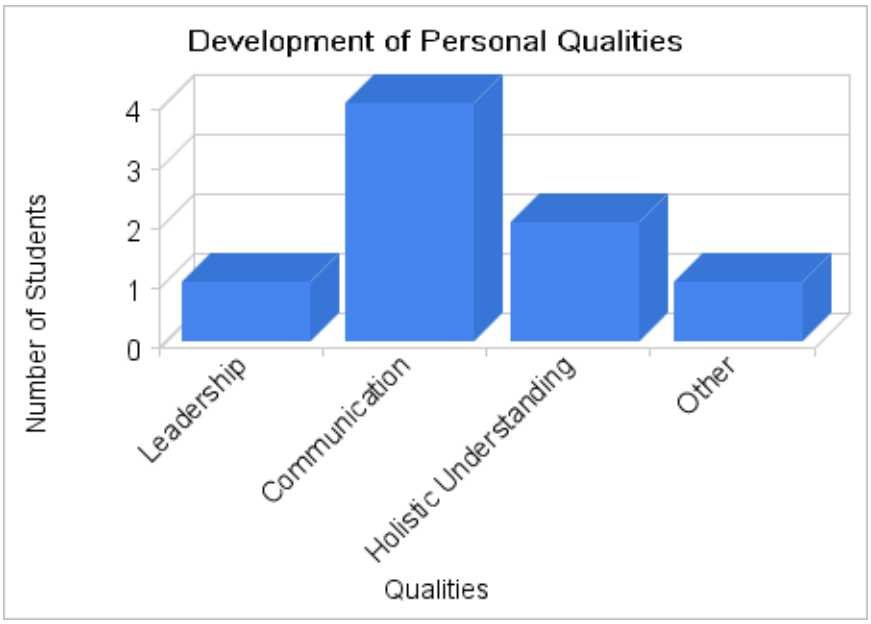


Figure 7.) Illustrates the qualities the students developed through the "How To" project.

## Conclusions

In order for the project to be a success, certain factors need to be present (which was learned after one failed attempt). The first is the need for face to face communication by the students and instructors to put a face and personality to each member of the group. Second is to survey the high school students earlier. The third is to plan out logistics from the onset of the project. This cuts down on any confusion and sets allotted time schedules since classes may be on separate campuses and meet at different times.

I conclude that there are certain advantages to service learning not standard in classroom dynamics. One such advantage is working with people from different backgrounds. The data in question 1 points to students realizing communication plays a key to solving societal issues. This project challenged both classes to step outside their comfort zone and communicate on a real issue. In addition, in two unrelated questions, 1 and 3, communication was a major theme in their answers.

The data shown in question 1 and 3 reaffirms the belief that service learning is helpful to students in gaining certain skills not accomplished in writing a paper. Although communication was not the focus during the project, the largest number of students mentioned it when asked what personal quality the students took away from the project. This leads me to believe the students may focus their efforts on communication throughout their careers, making them better engineers in the process.

Many of the students did not seem to have a grasp on varying engineering principles or social issues. While not a major concern since it is a freshman class, it is nonetheless a concern. I was surprised that none of the answers to this question were the project's intent to gain interest in engineering due to the lack of engineers in society. A possible solution may be as simple as giving examples of some engineering principles and social issues in the question. Another solution may be to integrate other societal issues throughout the project. I would like to point out it was not surprising sustainability was a social issue, due to the fact that the week before the lecture was on sustainable manufacturing.

Overall, the project was successful in meeting the objectives of offering middle and high students age appropriate building projects using a novel delivery system. This is an ongoing project and the material is currently being reviewed by the high school students and teachers. I believe the project material presented here is much more alluring to middle and high students and demonstrates a sense of excitement. However, we will know more when we get feedback. On another note, The ET students acknowledged there is more than technical knowledge to thrive in a professional world. The personal qualities developed during this project would be very difficult to obtain by other means. In addition, students preferred this creative outlet instead of simply writing a five-page paper.

## Acknowledgements

Graphic Design program teachers and students

High School Teachers and students

Service Learning Department

**Bibliography**


1. Sanders M., "The Nature of Technology Education in the U.S." 2008 American Society of Engineering Education.
2. Welty K., Katehi L., Pearson G., and Feder M., "Analysis of K-12 Engineering Education Curriculum the United States-A Preliminary Report" 2008 American Society for Engineering Educators.
3. McGrath E., McKay M., Schultz D., "Engineering our Future NJ: Promoting Engineering in K-12 Schools Through Professional Development, Policy Initiatives, and Partnerships" 2008 American Society of Engineering Educators.
4. Ragusa G., Khoo M., Meng E., Cocozza J., "Engineering Outreach: Connecting Biomimetic Research to Urban K-12 Classrooms" 2008 American Society of Engineering Education.
5. Boyle P., Houchens B., "Adaptive Water Laboratory for K-12 Outreach on Sustainable Water Use" 2008 American Society for Engineering Education.
6. Birnkrant M., Cathell M., Blount P., Robinson J., Fontecchio A., Fromm E., " Introducing Engineering through Candy" 2008 American Society for Engineering Educators.
7. http://howtoons.com
8. Lima M., Oakes W.C. “Service-Learning: Engineering In Your Community” 2006, Great Lakes Press Inc. pg. 301 Chapter 11 Reflection and Self Discovery.
9. Remick P., Cook F. “21 Things Every Future Engineer Should Know” 2006 Kaplan AEC Education, Chapter 1.
10. http://www.servicelearning.org/what_is_service-learning/service-learning_is/index.php
11. Defoe, D. “Robinson Crusoe” May 2003, Barnes and Noble.

## Appendix

### A1: Surveys to High School Students

The surveys created by the first graphic design students are outlined below:

**Student Survey for the How-To Project:**

A collaborative effort of ___ Mechanical Engineering students, Advertising + Graphic

Design students, _____ High School, and _____.

Grade Level:_____

Age:_____

Gender:_____

Interests (outside school):_____

Favorites:_____

websites:_____

TV shows:_____

Magazines:_____

Books:_____

Music:_____

If you would build something what would it be?_____

**A2: Peer Evaluations**

Your Name

Name of Team Member you are Evaluating.

Team member is dependable and responsible.

Team member contributes on a regular basis.

Team member submits work on time.

Team member supports other members of the team.

Team member focuses on team goals and objectives.

Team member puts aside personal preferences for the good of the team.

Team member practices effective teamwork skills.

Team member practices effective conflict management skills.

Team member demonstrates appropriate leadership skills when needed.

Team member contributes appropriate expertise.

Team member is open to constructive criticism.

Team member provides constructive criticism.

Comments

**A3: Reflection Questions and Student Answers**

Mechanical Engineering Technology Students were given reflection questions; below are three focused on service learning/outreach.

How can [engineers] work with other citizens together to solve problems? Why should they?

1. Engineers are able to realize ideas that can better serve the public. IDEAS

2. By making themselves available and just open/honest communication. I believe today to many people have a political agenda on when they speak on a subject and it's hard or the average citizen to grasp what is the truth COMMUNICATION

3. Its a good thing to get input from the people who use the products being designed. It will help the engineer to better understand what changes can be made to make a better item. Understand Problems

4. engineers need to work with other people because if they hang around us , they may start thinking as we do. how... is to just help them understand things around them, such as their environment. Understand Problems

5. They should listen to what the issues truly are. It's not enough to be smart and know how to fix things. They must be able to listen to what truly needs to be fixed. They live in this society too. We all want to live in a better world. COMMUNICATION

6. Engineers can ask for the direct problem and figure a way around any bumps or resolve the problem at hand. Engineers are employed to simplify the average citizens, including them selves. If enineers neer worked with citizens we may not be able to solve any issues that pretian to people. COMMUNICATION

7. Getting other citizens involved is good. More ideas more man power. NOT SURE

8. Engineers can not be experts in every aspect of a project; they must relie on other experts to complete a large job. Interconnectivity

9. With open minds, that is how engineers can work with "other citizens." That goes both ways. We all need to take the chips off our shoulders. Why should we, because the different view that we bring in looking at things OPEN MINDS

Think of a [engineering] principle that can be applied to help understand a social problem. How does your thought process as a [engineer] affect the way you view social issues? Can social issues affect the way you do science?

1. Engineers want to find a method or process of solving a problem but social issues such as the environment can affect the way an engineer solves those problems.

2. Yes I believe just from the lecture on sustainable manufacturing help me understand some of the social issues that are discussed today such as waste and greenhouse effect

3. not sure

4. polution is a good social problem, sustainability is an answer that might help arrest it.yes by cause and affect.

5. You look at any situation more analytically. You want to know why a situation is the way it is. What could have been done different? What should have been done different? What can be done to fix it? You have to be interested in these questions before you can change anything be it business, manufacturing, or social.

6. My thought process may help in social issues by breaking down the debut, and try to find the cause of the issue. Then with the orginal problem solved, depending on the circumstance, it may resolve the issue in hand. Yes depending on the issue it may affect the process plan depending on the varibles.

7. Yes, Because if the communication is not there nothing goes correct.

8. Force multiyplyers. If you can get more people to communicate then larger amounts of work can be done in a timely manner. I see social issues in a can or can't work work viewpoint. Social issues may cause the need for a specific science being used to deal with a problem.

9. I'm not sure. I haven't really thought that any problems that I have faced were or could be related to social issues. Like I said previously, logically, steps by step I guess not really sure. I'm sure social issues affect the way we do science. An issue that touches me on a personal level would be one that I may per sue. I really haven't thought about the "social" side of the house

What personal qualities (e.g. leadership, communication skills, compassion, etc.) have you developed through service-learning? How will these qualities help you in the future?

1. I found myself to be the leader of the project as I was the one to direct the group. I know that I can be a project leader when I need to be and I think that I enjoy being the leader.

2. Again to go more in depth on things I may be doing or understanding.Understanding the processes of things and why we need to follow certain steps as we take on new task

3. More communication

4. i have to say that learning that it is very important to communicate and as a skill i need to devote more time to it.

5. There comes a time when you just have to take a deep breath and jump. Once I opted on an idea, I was able to see it through this whole process. You have to stand by your vision. They weren't real sure about the poster concept, but in the end they were both glad that's the way we went.

6. This experience has taught me that everyone had a responsability in regaurds to this project. It wasn't as if one person was doing all the work but each indivisual was asigned a job and each person took that job and continually asked each of the team members if this was okay. In future jobs I'll beable to recieve project jobs and communicate with the other team members to achieve goals.

7. I expect to much from people. I learned that you can not let some people do it there way.
I was nice and tolorant of my team mates. I did this to move the project along in a positive manner.
This method will get more work out of people than being ill and hard to work with.

8. Communication skills, lack of. Different approach rather then e-mail.