

AC 2007-984: ENHANCEMENT OF CHEMICAL ENGINEERING INTRODUCTORY CURRICULUM THROUGH SERVICE LEARNING IMPLEMENTATION

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Enhancement of Chemical Engineering Introductory Curriculum through Service-Learning Implementation

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Abstract

As a part of a departmental curriculum reform project supported by the National Science Foundation, service-learning has been implemented in the first ChE sophomore-level course by a collaborative student and faculty effort to achieve the following:

1. Increase retention through student engagement with interesting and insightful projects that apply engineering principles to actual problems.
2. Engage students in social responsibility through real life projects and applications that in turn directly benefit the community and its members.
3. Build working relationships not only through student team work, but also through industrial and non-profit networking.
4. Create excitement for engineering through the promotion of sustainable technologies, project management, hands on experience, open-ended problems and project based learning.

To achieve these goals the first service-learning project has been given to the introductory level material and energy balances class for the fall of 2006. The general process for the project is as follows:

1. *Formulation of project:* Initial contact was made with many community based services and non-profit organizations, asking for service-learning opportunities. Proposals were discussed and selected according to pre-established project specification criteria.
2. *Project promotion:* Student teams assigned project with general outline and guidelines. Project requires planning, attention to detail, extra research for understanding of sustainable technologies for a creative solution, and transfer of learned concepts.
3. *Designing and Project Completion:* Field experts, professors and upperclassman mentors are available for guidance, support and collaborative learning.
4. *Project Reflection:* Written reports and oral presentations graded by professors and community representatives based on a rubric, including creativity, presentation, detail and application of engineering. Suggestions and constructive criticism given. Reflection on collective learning.

Service-learning benefits both the students participating and the community. Service-learning projects help students to establish connections between the concepts learned and the real life; promote team work; teach professional ethics and social responsibility; and provide opportunities for professional communication. In addition, basic economics will

also be learned, as the students must take into account viable engineering and differentiate between consumer wants and needs. The community benefits through the students' work on real life problems and situations, which ultimately make a difference in peoples' lives.

In the fall of 2006, the class has been presented with a project agreed upon through collaboration with the department and Habitat for Humanity. The project is to design a "green" home, focusing on conservation aspects such as energy, water and waste. Habitat for Humanity construction advisors, professors and upperclassmen mentors will be there to advise and learn with the students throughout the project. Upon completion of the project, a paper and oral presentation will be graded by a rubric focusing on creativity, detail, implementation of curriculum and teamwork.

This presentation will focus on the implementation of service-learning in the classroom, student performance on the project, and lessons learned for the next iteration.

Introduction

The Artie McFerrin Chemical Engineering Department at Texas A&M [1] has a total enrollment of approximately 650 undergraduates participating in a 132 hour program. Within the undergraduate curriculum, there are a number of chemical engineering classes, ranging from materials science to thermodynamics to numerical analysis to heat transfer in which certain aspects of service-learning can potentially be implemented. The current senior design class is based and revolves around one major project that is usually sponsored by a company. The company presents a real-life problem or initiative that they would like see solved to the senior design class, which in turn works in teams to solve the project based off their prior knowledge, curriculum and work experience. Upon completion of their senior design projects, the work is typically taken back by representatives to their company for legitimate consideration. This is a major example of collaborative effort on a project between the department and industry; however, there is one major component missing from this project to actually qualify it as service-learning: service to a needy cause.

Therefore, as seen above, the implementation of service-learning into a class must be more or less seamless within that class to achieve all the objectives listed above. The goal of the senior design class, as it should be, is to ready graduating seniors for classical chemical engineering problems that would be faced in an industry situation by pulling together four to five years of previous education and work experience. While upper level classes tend to focus more on the theoretical application of highly involved math, science and engineering, it seems that service-learning is more difficult to implement in these classes without greatly disrupting their purpose and perhaps causing more of a problem than a solution academically. However, the importance of service-learning is great and more evident every day, as our world must learn to take responsibility for its choices. Therefore, there is an untapped potential in the lower level classes that allows service-learning to be implemented into the classroom at an even more influential stage in a student's college career. The majority of students who drop out of engineering disciplines do so during their freshman and sophomore years, and by implementing

service-learning, a visible application of curriculum, the goal of enrollment retention can potentially be adequately addressed during these crucial years.

As such, the ideal place to begin service-learning at Texas A&M University would be in the general engineering courses all freshman engineers are required to take. However, within the Chemical Engineering department the most obvious place to start is the first chemical engineering class offered to students, the material and energy balance class, which will be referred to as CHEN 204. Within this class, there are many general chemical engineering principles that are covered and can be applied in many different types of projects that qualify as service-learning. In the past, the class was required to do a project up to the professor's discretion. Therefore, during the summer of 2006, it was decided to implement service-learning through the rejuvenation of the project aspect of this course.

Formulation of Project

Research began during the summer of 2006 by an undergraduate student and the course professor, locating potential projects and contacting the necessary parties that would be involved within the communities of Bryan and College Station, Texas. Parties such as the College Station Water Department – Carter's Creek Water Treatment Plant, Habitat for Humanity, TAMU Recycling and the Brazos County Health Department were contacted as potential third parties to partake in the service-learning implementation within the chemical engineering department. Meetings were held with the student liaison, the professor and representatives from each separate organization. After all meetings were held and potential projects were discussed, the decision was made to base the project around the Habitat for Humanity proposal.

There were several different projects that Habitat for Humanity proposed for the CHEN 204 class. However, a major component of service-learning is implementing a project that will reinforce the particular curriculum of that class, and therefore, the final project decision was for the students to design a 'green' home, considering the specifications, needs and requirements of Habitat for Humanity. This project would focus on making the energy, water and waste systems of the house the most efficient to save the families of Habitat for Humanity in utility bills. Therefore, the students would eventually perform mass, material or energy balance calculations on the house they designed and would also submit a comprehensive budget, which was to be kept under the \$60,000 Habitat for Humanity standard. As the project reinforced the curriculum, it also would teach project management skills, communication skills and social responsibility. Therefore, through the project the students would not only be applying their engineering skills, but they would also get first hand experience working with industry and non-profit organizations in a professional sense. Also, the service aspect of the project would be addressed through studying the needs of the families of Habitat for Humanity and identifying with societal issues that face these families everyday. Collaboration with Habitat for Humanity for students to actually see a home being built, visit a family in the program, and speaking with representatives that have dedicated their lives to this program is necessary in order for a meaningful service to be provided.

Project Promotion

As a custom in the CHEN 204 class, the class was divided into teams of four people to complete homework and project assignments. Teams were formed at the beginning of the semester, and the students had previous experience working together on homework assignments before the project was assigned. The project was assigned approximately a month into the semester, and the class was given a project description that read: “As a team, you are concerned about future levels of energy consumption, water use, and waste. You envision a green home that will minimize the energy consumption, water usage, and waste. Your team is going to conceptually design a green home for Habitat for Humanity, and specifically design water and energy systems.” Therefore, the project was purposefully set to be as real-life, open-ended, and hands on as possible, so the teams could take ownership of the projects and have the freedom to make their own creative designs within general stipulations for all Habitat for Humanity houses.

Before the project was assigned, the professor and the student mentors identified that this project could seem extremely overwhelming to students, and therefore, it was suggested to provide the students with a general project management outline that included incremental due dates for essential parts of the project that were identified as “milestones,” as termed by Marybeth Lima and William Oakes in their book, Service-Learning: Engineering in Your Community [2]. Figure 1 shows the basic ideas that were represented within the project management plan, as well as the incremental assignments.

| Milestone | Due Date |
|--|------------------------------|
| 1) Project Charter & PERT or Gantt Chart | Monday, October 9, 2006 |
| 2) Research of Energy Systems | Monday, October 16, 2006 |
| 3) Research of Water and Waste Systems | Monday, October 23, 2006 |
| 4) Preliminary Design Plan | Monday, October 30, 2006 |
| 5) Final Design and Calculations | Wednesday, November 15, 2006 |

Description of Milestones:

- 1) **Project Charter & PERT or Gantt Chart:** These are two types of project management techniques that are often applied in industry. They will help you to keep your project on task and not fall behind.
- 2) **Research of Energy Systems:** Research all of the topics under the Energy Consumption section of the project description. Find five sources that address the issues described and summarize the information in those sources. Sources can also be people, such as professors or professional experts! Example: Find a book or website that goes into detail about solar power used in houses. Be sure to tell what solar power is, how it is specifically used in a house, the advantages (clean energy) and the disadvantages (inefficient, high overhead cost) to this alternative energy source. This is where your ideas for your energy source will come from!! Be creative!!
- 3) **Research of Water and Waste Systems:** Research the topics listed under the Water Usage and Waste sections of the project description. Find five sources that address these issues, focusing on usage for a ‘green’ home. Summarize the information presented with details, advantages and disadvantages.
- 4) **Preliminary Design Plan:** Now that you have researched the many different types of energy, water and waste systems for a house. Propose your preliminary design plan. Example: Team Green will use wind as their alternative energy source, energy saving appliances from _____, recycled construction materials such as _____, and an efficient plumbing and irrigation system such as _____. Fill in the blanks with the information found from your research! Also, give such details that will apply to these systems, and why you chose them.
- 5) **Final Design and Calculations:** Now, you have your preliminary design! Don’t stop here! Tweak your design for ultimate optimization and creativity! Finalize your design and do the calculations described in Design of Water and Energy Systems in the project description. Do these calculations several times, changing up different design aspects to be certain of your final design!

Figure 1: Project Management Document

As it is seen in Figure 1, creativity was highly stressed in the project; however, it seems that engineering students are accustomed to receiving a project outline that basically completes any formal planning and removes the need for logical and methodical thinking in the beginning of the project. Therefore, the students' tendency was to panic before fully thinking through the project. At the same time, the professor and student mentors also identified the lack of knowledge these students had pertaining to designing a home, as they are chemical engineering students, not architecture majors. Therefore, to help students clear these initial hurdles a series of short lectures were given outside of class by those who are experts in various areas that pertain to the project.

The Property Development Coordinator for Habitat for Humanity in the Bryan/College Station area [3], Mr. Jim Davis, gave a short lecture concerning the particular requirements and specifications that Habitat for Humanity required in their homes. Mr. Davis gave a handout that had particular building details and suggestions for the students' designs. Mr. Davis also spoke on behalf of Habitat for Humanity, explaining that Habitat for Humanity is not a give-away organization as many think. The families must first put in a number of sweat hours on building Habitat for Humanity homes and be accepted to the program before they can buy a home at cost through a zero interest 20-30 year mortgage. Therefore, students not only learned about the requirements for their home designs, but they also got an insight of things to consider when implementing certain aspects of their design. For example, students were warned not to put technological systems in their homes that would frequently break and would be high in maintenance costs because this would be an expense that home owners could not handle.

Professor Jeff Haberl from the Energy Systems Laboratory [4] within the Department of Architecture at Texas A&M University and PhD student, Mini Malhotra, spoke to the students about past and current projects between the College of Architecture and Habitat for Humanity. Both speakers were able to summarize past research and give feasible ideas to implement in the students' designs.

Also, Dr. Mahmoud El-Halwagi, a professor within the chemical engineering department, spoke to the students about making simple material and energy balance calculations pertaining to such everyday cases, such as showering, flushing the toilet and appliance usage. This prepared the students to make their own calculations based on the certain systems they implemented in the design of their homes.

The requirement for these lectures was that at least one person from each team must be present to take notes and be able to relay the information to their teammates when working on the project. Another purpose in having these lectures was to provide the students with contacts who were considered experts in various areas that pertained to their project. Therefore, it was stressed to form relationships with various types of people involved in academia, service, and industry through which the students would learn valuable people and communication skills. While a range of subjects were covered by the lectures, there are more topics that could potentially be added in the series, such as project management skills, writing and presentation skills and service-learning itself.

Designing and Project Completion

During the two months the students had to work on the project, there were several incremental due dates as shown above provided for the purposes to keep the students on task. Being a large project, the students could get behind easily, procrastinate, and find themselves in trouble the week before the project was due. Therefore, the incremental due dates would not allow the students to fall behind. During the time of research, students could ask the professor, student mentors or lecturers for help and advice. However, during this time, it was made clear to the students that none of these people had the correct answer because there was not one solution to this problem, but many complex and unique answers. It was also stressed that the professors and mentors were learning at the same time as the students, and therefore, patience was key in making this project a success. The grading rubric for the project is shown in Figure 2, as this was an important part for the students' verification during their planning period.

This is an open-ended project, be as creative as you can be. You will submit a report (50%) and present your project in front of an audience (50%). Your project presentation will be judged by your fellow students, a team of faculty, and a Habitat representative. Your project will be evaluated as follows:

- Creativity (40%)
- Effective use of CHEN concepts (30%)
- Detail and effort (10%)
- Written/oral communication skills (20%)
 - Conveying your ideas to the audience(or the reader)
 - Presentation (slides/report)
 - Composure/answers to questions
 - Teaming

Figure 2: Grading Rubric

Along with this grading rubric, a site visit to Angels Gate [3], a for Humanity neighborhood, was a mandatory requirement of the project. Site visits were planned on two separate weekends and lasting only an hour in order to accommodate student schedules. Due to the large size of the class, over 100 students in two different sections, and scheduling reasons, the class was not able to actually work on a Habitat for Humanity class, which was the original idea. However, the site visits let the students see what type of house they would be responsible for designing. This site visit allowed students to have a visual to work from, rather than only theoretical principles, as well as reinforcing the sense of responsibility to the people that could be affected by their project. Engineering decisions directly affect people on a daily basis and whether the general public realizes this or not, it is essential for engineering students to meet and understand their societal responsibilities early in their careers.

The students being prepared through many different class activities worked to present their ultimate designs in a report format and through an oral presentation. There was no requirement to the report size, as long as it adequately fulfilled the project description.

The teams were given seven minutes each to present their projects during the already scheduled recitation period. The presentations were graded by a representative of Habitat for Humanity, the professor of the class, a student mentor, and other invited guests that had participated in the initial concept of implementing service-learning within introductory class. Students came up with many creative ideas to present their final designs. One student team gave a three dimensional virtual tour of the house. Another example is shown in Figure 3. This is a model home built by a student team, when the roof is lifted the actual floor plan of the house is seen.



Figure 3: A model home built by a student team.

Most student teams were able to present an outline of their calculations and show the cost savings, energy, water, and waste minimization features of their designs in the limited time they were given. However, some student teams went overtime, some presentations were purely qualitative. The project team, the professor and the student mentors, has decided that the students needed more guidance in oral presentation. Next time, students will be given a short training on how to present.

Project Reflection

Several pieces assemble to complete the reflection process. A team assessment, reflection piece and an overall survey was issued to all students in order to gain a general evaluation of the project.

A team assessment document adopted from Felder and Brent [5] was issued to every student by the professor via email. The document was kept completely confidential, allowing each team member to honestly comment on their teammates' work throughout the semester, including homework and project responsibilities. This assessment also included a self critique, which could be used as a gauge in comparison to how that individual was grading their teammates.

The students were advised to write a reflection piece within their paper to be able to comment on the project, and also, take time to reflect on the many things they learned

during this process. This reflection piece was meant to be a part of the report where students could truly tie in the service aspect of the project with the learning of engineering principles. Without reflection on the overall impact, the relationships formed and the service provided to the community, the project becomes another engineering assignment and does not fulfill the definition of service-learning.

The overall project survey was made with an online survey service, and the web address was emailed to all the students. This survey was completely anonymous, as to give the students complete freedom to express their opinions and candidly make criticisms and suggestions for future projects without having concern of this affecting their grade. Due to the anonymity of the survey, only 62 of 100 total students took the online survey. However, the results of the survey provided valuable information and highlighted areas for improvement for the next service-learning project.

Analysis of Project

Analyzing the results from the online survey provided the most detail about the students' perceptions of the overall project. The survey focused on several issues pertaining to service-learning, and the questions can be categorized virtually into two fields: those that apply to the service aspect and those that apply to the learning aspect. However, the learning aspect can be broken down into two individual areas: the learning, as in reference to the curriculum and course material, and the learning, as in reference to additional skills in the form of communication, team work, and project management. Therefore, the results will be discussed as pertaining to these three areas, and the final conclusion will draw a more general summary of the project.

In dealing with the service aspect of the project, several questions were asked to see the affect this project had on the students' opinions concerning community service and responsibility. Of the students who took the survey, 91.9% attended one of the two site visits to Angles Gate, the Habitat for Humanity neighborhood, and 71% said it helped them have a better grasp on the issue that the project addressed. These statistics show that the site visits assisted the students in making their final designs by providing a better defined foundation from which to begin. In addition, 75.4% said that they are more apt to volunteer for more community service events like Habitat for Humanity due to this project. This statistic is one of the most crucial gauges of the project's success, as it motivated the majority of the students to become more involved in the community through service to others. Also, students ranked how the project reinforced their societal responsibility on a scale with A being excellent and F being failing. Of those students who took the survey, 25% gave this an A, 56% gave a B and 15% gave a C. This is a good result for the first time a service-learning project has been implemented; however, the majority rests below excellent, and as increasing societal responsibility is one of the four major objectives of the project, this result shows that there is room for improvement in the design of future projects.

With questions pertaining to the learning done within the project, the results varied with constructive criticism being offered by the students. However, one of the lowest opinions given was in relationship to the project reinforcement of class curriculum, which was

graded on the same A to F scale. Of the students who took the survey, 23% gave this a B, 33% gave a C and 31% gave a D. This shows by far that the students did not believe that the project reflected the material presented in the classroom. Taking a deeper look into the comment boxes offered on the survey, it became evident that the students learned much from the project, but many responses suggested limiting the project strictly to studying the energy and water systems rather than have the focus on designing the house. This is reflected directly in one student's comments: "Good examples of how this project incorporated course materials were water and energy balances. For example, calculating how much water can be saved by collecting moisture removed by an air conditioner required the use of several techniques used in this course such as material balances, equilibrium relationships, humidity equations and more. While this is great, I feel more could be done along these lines." Another statistic that reinforces this same theme is the results of grading the clarity and conciseness of the project outlines. Of the students, 33% gave a B, 30% gave a C and 23% gave a D, showing that the majority of the students thought that better, more defined outlines would have given the project a better focus. This sentiment was reiterated in the students' comments, asking for "definitive clear and concise project outlines" and expressing that the project was "too broad to focus on everything." Therefore, students offered more suggestions for upcoming projects, such as dividing the different systems in the home and assigning only one team to each area, making it a class collaboration. As this project was meant to be open-ended, one student positively reflected that "I liked how we weren't given major constraints. This allowed for more freedom of design which I really enjoyed." However, open-ended projects can seem to grow into larger problems without clearly defined outlines from the beginning, causing frustration and confusion for the students. Therefore, future projects must allow the students the freedom of design, while offering them clear objectives, stipulations and expectations from the class and the service party.

Learning of the desired skills sets that were outlined in the four major objectives of this project was exceptional. The best grade the project received was that relating to team functionality, which 46% of survey students gave an A and 38% gave a B. This is an exciting result, as students typically complain that the majority of their teams were dysfunctional and the majority of the work was only completed by a few team members. Therefore, the magnitude of this project forced students to work in their teams, as every member was needed for ultimate completion. The students were asked to rank how the project instilled other skills that were outlined previously on a scale from 1 to 5, with 1 being the lowest and 5 being the highest. The instillment of project management skills was given a 5 by 35% of the survey students and a 4 by 44%. The instillment of team working skills was given a 5 by 32% and a 4 by 52%. The instillment of real world decision making was given a 5 by 19%, a 4 by 45%, and a 3 by 19%, and the instillment of economic analysis was given a 5 by 26%, a 4 by 42%, and a 3 by 21% of students who took the survey. These statistics show that the project successfully implemented team working and project management skills. The students felt that the real world decision making could have been better represented through the project, and this proves to be an area of improvement for future project outlines. Also, the economic analysis area of the project could have been better applied, according to the statistics. Looking to the student's comment box, there are positive responses given in regards to the learning of

these skill sets. One student commented, “The project was a good exercise in team building and research related skills,” while another reveals, “I certainly feel that this project has greatly improved my research skills.”

Conclusion

Prior to implementing the service-learning project into the CHEN 204 introductory material and energy balances class, four main objectives were outlined that would be addressed by the implementation of service-learning. Briefly, they are (1) increasing retention rates, (2) engagement in social responsibility, (3) building working team skills and (4) creating an excitement for engineering. The success of the project must stem from the overall analysis of the accomplishment of these objectives by the project.

In regards to increasing retention rates, we cannot yet prove that this project fulfilled this objective, as the semester of its inaugural implementation just ended. However, with further implementation of such projects, we believe that the retention rates, especially women and minorities within chemical engineering, will increase due to the excitement and applicability the projects can bring to the curriculum material. Young generations born between early 1980s and 2000 want to see their profession as a vehicle to help make the society better [6], [7]. This hypothesis can be supported through the many positive aspects that the first project reflected, such as an increase in student desire to participate in service events, and one statistic that showed 56.5% of the students wishing to continue on the project until their Habitat for Humanity designs were actually implemented. Therefore, even though the students expressed concerns about the project and certain aspects of its implementation, the overall objectives were addressed at a successful level in all cases. This is not to say that there is not room for improvement, as the purpose of education is to constantly look for better ways to impart essential kernels of knowledge to future generations. Therefore, the project implemented in the CHEN 204 class during the fall of 2006 was a learning experience for students, professors and all involved, and together these parties have identified positives of the project and areas that need improvement. The collaborative effort for the future can best be described by this student comment: “Projects are always better the second time around. Next year the freshmen will be able to talk to us to see how we approached the problems.” This comment also shows an unexpected result that came from this project: a connection between past, present, and future students that only strengthens the positive implementation of service-learning. Through dedicated professors, students and community leaders, a difference can and will be made at Texas A&M University.

For Instructors

After the first implementation of the described project, we have come to several conclusions that we would like to share with instructors who might be interested in incorporating service learning projects into their courses: (1) Share and discuss the learning objectives of the project with the students at the time the project is assigned. This would better define the project and bring focus to the objectives. (2) Do not attempt a project that is too broad. (3) Clearly define the boundaries of the project but also have sufficient flexibility to promote creativity. (4) Train and guide students in project management skills. The project becomes manageable and not so overwhelming if it is

broken into parts and each part is collected as an assignment throughout the semester. This not only allows students to learn simple tools of project management, but also helps them to learn the steps to be taken for a successful completion of a project. Finally, (4) guide the students in terms of calculations they can do that are appropriate to their background and also relevant to course material. In overall, this project has created excitement in a very traditional chemical engineering curriculum and a sense of citizenship both among the students, instructors, mentors, and all.

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