Community-based projects by first-year engineering students

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Abstract
At Elizabethtown College, for the last two years in the Fall semester of our “Introduction to Engineering” course, we have replaced our traditional “canned” design activities with engineering projects based in the community. In the Fall semester of 2003, 24 students participated in the Introduction to Engineering course, completing seven projects in the community, including two wheelchair ramps, a jig set to perform life skills, a dollhouse for victims of abuse, a vertical maze for a children’s display, and a handrail system for a walking bridge. In the Fall of 2004, 36 students worked on ten projects including a wheelchair ramp, proximity sensors for a power wheelchair, toy-boxes for families in transitional housing, basement access for a community center, CAD and GIS map work for a neighboring borough and two dollhouses for a fundraising auction. These projects are well suited to first year engineering students, as they generally do not require skill-sets developed in upper-level science and engineering courses. Yet, these projects are genuine, have real clients, and are able to address many important topics in the Introduction to Engineering curriculum, including teamwork, problem solving, design, communication skills, project management and the application of basic engineering principles. In this paper, we address the merits and challenges of these community-based projects, as well as provide an overall discussion of the experience.

1. Introduction
Similar to many engineering programs, Elizabethtown College runs a semester long “Introduction to Engineering” course for first year engineering students. This survey-type course is “half” credit (two academic credits compared with the typical four credit course at the College) and meets four hours each week for the Fall and Spring fourteen week semesters. Our Fall semester course is a true survey course, briefly covering the topics of history of engineering, engineering majors and career paths, problem solving, design, project management, teamwork, oral presentation skills, technical writing, and some basic computing skills using a spreadsheet (statistics, solution of equations, and optimization). Most of these skills are relevant to all engineering majors and can be introduced without the need for a rigorous mathematical framework. To connect all of this material together, team-based engineering projects are typically assigned. A significant challenge for first semester first year engineering students is to find projects which are both challenging enough to require real teamwork and project management, while not having unreasonable time and skill-level demands. We feel it worthwhile to discuss one such domain of projects with our recent experience with community-based projects at Elizabethtown College.
Elizabethtown College (an undergraduate college of 1800 students in Lancaster County in Pennsylvania) has the motto of “Educate for Service” and continues to grow programs of “Service Learning” through its Center for Global Citizenship. Through this Center, professors can find administrative support for incorporating Service Learning into their courses. Several engineering departments worldwide have strong Service Learning components in their curriculum. For example, motivation for these projects came in part from information about Purdue University’s EPICS\textsuperscript{2} program. A key factor for our implementation of these projects at Elizabethtown was the availability of administrative support to locate potential projects through the Center for Global Citizenship as discussed in Section 3.

Starting in the Fall semester of 2004, projects for the Introduction to Engineering course were converted entirely to community-based projects. Through the aid of the Social Work department and the Center for Global Citizenship, fourteen potential projects were located and listed for the students. The 24 students in the course formed seven teams; each team was assigned a project after specifying their top three choices from the list. (In most cases, students were able to have their top choices.) The projects included the design and construction of 1,2,3) three wheelchair ramps, 4) a jig set to perform life skills, 5) a dollhouse for victims of abuse, 6) a vertical maze for a children’s display, and 7) a handrail system for a walking bridge.\textsuperscript{3} A similar scenario occurred in the Fall semester of 2005 with 36 students working on ten projects including 1) a wheelchair ramp, 2) proximity sensors for a power wheelchair, 3) ten toy-boxes for families in transitional housing, 4) basement access for a community center, 5) CAD and GIS map work for a neighboring borough, 6,7) two dollhouses for a fundraising raffle, as well as repeat projects from the previous year.\textsuperscript{4}

The first year engineering students surprised us with their diligence, creativity, and initiative in completing these projects – excellent work was done in most instances. The students appeared to appreciate having real clients with a genuine need for the product. In the process, we were able to address many important topics in our Introduction to Engineering curriculum, including teamwork, problem solving, design, communication skills, project management and the application of basic engineering principles. To date, the projects have been well-received by our students, our department, and by the College as a whole. Indeed, we have had collaboration on three of the projects from the outside departments of Social Work, Occupational Therapy, and Fine Art. In this paper, we discuss the motivation for the projects, essential support provided by the College, our implementation, and some general concerns. Additionally, we conclude with a synopsis of eight of the projects to highlight them and some issues that arose.

2. Motivation
Today’s engineer needs to have many talents beyond the ability to solve technical problems – foremost, the ability to communicate clearly to non-technical co-workers in both oral and written form, but also the ability to effectively manage time and work within a team. By assigning a team-based project with a substantial time commitment and real customers, first-year engineering students are afforded the genuine need to work together cooperatively and effectively manage time. Indeed, almost all of the topics covered in our Fall semester first year Introduction to Engineering course are addressed within these projects: project management is addressed through both the obvious time constraints and specific methods such as Gantt charts; oral and written communication skills through multiple presentations and reports; and teamwork,
design, problem solving, and the application of basic engineering principles through the completion of the project.

The specific use of a community-based project, however, has several advantages over a more fabricated project as was previously used in the class (previous examples include mouse trap cars, can crushers, and a new toy or game.) The community-based project allows for a real customer, as well as substantial motivation to complete the project for a customer that generally has a real need and appreciation for the product. Less tangible are the unstated “Service Learning” objectives which include exposure to a diversity of people in terms of race, abilities, and economic status. For example, the customers in the wheelchair ramp projects were generally low-income families in the inner city (Harrisburg and Lancaster) and the customers in the “Jigs for Life Skills Project” were elementary and high school aged students with Down’s Syndrome. While we (McBride and Fullerton) do not specifically address the Service Learning components of the project with the students, it is clear that they take seriously their responsibilities to their customers and have positive new experiences with people differing race, physical, mental, and economic status.

3. Help from Center for Global Citizenship
For us (McBride and Fullerton), the biggest obstacle to implementing the community-based projects was finding a sufficient number of sites and appropriate projects. This was a truly daunting task and it is unlikely that the projects would have proceeded without support from outside the engineering department. The majority of the projects were located through the Center for Global Citizenship (Bergel). This support is essential and can likely be provided at any college or university that has a Social Work department or program. While finding the projects without this support is possible -- almost all of the projects were located either through social services organizations (e.g., Office of Aging, YWCA, United Disabilities Services), schools, or municipal offices -- it is our experience that time demands are such that outside assistance is essential.

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Location</th>
<th>Team Size</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximity sensors</td>
<td>United Disabilities Services, Lancaster</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3-4 student team)</td>
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<tr>
<td>Example: Audio Signal with possible override.</td>
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<tr>
<td>Wheelchair ramps</td>
<td>Office of Aging, Harrisburg</td>
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<td>2. (6-8 student team) Harrisburg City, Wheelchair-bound man.</td>
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<td>Wheelchair ramp, 22 inch rise</td>
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<td></td>
<td>3. (5-7 student team) Fishing Creek (outside Harrisburg), about a 30-40 minute drive.</td>
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<tr>
<td></td>
<td>Wheelchair ramp, 15 inch rise</td>
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<tr>
<td>Toy-boxes for families in transitional housing (Harrisburg)</td>
<td>Brethren Transitional Housing, Harrisburg</td>
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<tr>
<td></td>
<td>(3-4 student team) (+ 3-4 Art students to decorate.)</td>
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<td>Design and build toy-boxes for up to 8 families in transitional housing. (Transitional housing is for single mothers working to make it on their own. Families can stay for up to 2 years in the apartments.)</td>
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Figure 1: Sample project list as presented to the students for choosing project preferences. Contact information was provided after projects were assigned. All additional design constraints were specified by the students following meetings with the customer.
In our case, the Center for Global Citizenship (Bergel) located approximately fourteen viable projects (projects that were neither too simple nor too difficult) which were then confirmed and listed for selection by our students. (A sample listing is provided in Figure 1.) This project location and specification took approximately 40-80 hours the first year, but was reduced in the second year after contacts were established and people were more familiar with the program. After this initial work prior to the semester, no further assistance was needed from the Center for Global Citizenship, though some consideration of follow-up studies has been mentioned.

4. Implementation
The projects were assigned in the third week of the semester. Students reviewed the list of potential projects and submitted their top three preferences. Individuals could form their own teams or merely specify their interests and allow the professors to form the teams. Teams of between 2 and 6 students were formed based on their preferred projects. (Projects with greater time demands were assigned more students to better weight the workload in the 2nd year). The teams were then provided contact information for their customer and required to report back within one week with an initial one to two paragraph project statement and schedule. Three weeks into the project, a design presentation was required. In most cases this required a design sketch, required materials, approximate budget, and timeline / simplified Gantt chart. By this time, students were required to have met with their customer and worked out a viable design.

The final project was due approximately eight weeks after it was assigned. At that time, students were required to give practice presentations to the professors. One week later (following Thanksgiving break) a final presentation was made (open to the public) showcasing the projects. The final presentation required photographs of the product, as well as design, materials, and budget information. Additionally, a final paper was required summarizing the project and providing essential data such as budget information. A more detailed assignment list is provided in the Appendix.

5. General concerns
An initial concern of ours was that the students would need substantial supervision in the process of contacting the customer and completing the project, requiring much travel and time on our part. While it was important for us to discuss design plans and maintain regular deadlines, a remarkable aspect of the projects was that once assigned, the majority of teams needed little supervision. Indeed, in most cases, we had no need to contact the customer after assigning the project. It was evident merely by talking with the teams and looking at their photos and designs that they had discussed needs/plans thoroughly with the customer, and done most of the proper research and planning. Because the students were highly responsible in all instances, we were able to evaluate plans, make suggestions, point out deficiencies in an efficient manner. Indeed, in both years we have assigned these projects, the first-year students have shown remarkable maturity and responsibility in dealing with the customer and completing the projects.

That being said, we have had students not perform well on their projects. As expected, we have had a number of individuals that lost interest in the major early on and perform below expectations. In some cases, this merely puts an extra burden on other team members, but at times has led to an overall poor project. An advantage of our current set-up, with many projects
to select has been that these students prone to poor performance appear to choose projects perceived as requiring minimal work and without a customer that will be sorely disappointed with a poor project (e.g., dollhouse for auction).

A final major concern is workload. Most of the projects require substantial workloads – with wheelchair ramps generally being the most time consuming. The current course is two credits out of a typical eighteen credit load for incoming first-year students. Combined with rigorous physics and calculus courses, the load is a concern. At the beginning of the course, we suggest that each student should commit forty to fifty hours to the project. Specifically, we suggest four hours outside of class for each of the eight weeks of the project plus approximately ten work hours provided during regular class hours. By resizing our teams based on perceived workload and better estimating workload, we feel more confident that we are not overburdening the students. For example, the group of five students working on the wheelchair ramp in the Fall of 2004 recorded 209 total work hours; with proper time management, this heavy workload still falls within the range of forty to fifty work hours suggested at the beginning of class.

6. How things turned out
In lieu of delving into all seventeen, eight projects are highlighted below to show some typical aspects of the community-based projects. Each project highlights at least one point of interest at the end, such as successes, lessons learned, and concerns.

6.1) Wheelchair ramp in Manor township
In the first year these projects were assigned, McBride substantially underestimated the time and cost for the completion of a wheelchair ramp. A wheelchair ramp requires approximately one foot of length for every inch of rise; thus, the thirty inch rise required for this wheelchair ramp required a thirty foot long ramp (Figure 2). This ramp was designed and built by a very talented team of three (yes, three) students. The students convinced friends and family to help in the project. They made detailed schedule at the start of the project and stuck to it, working most weekends as well as several weekdays. The final cost of the ramp was $1500; most projects were completed for individuals or organizations with financial need and were constructed at no cost to the customer. Projects were funded by the College, through material donations, and through an outside donation of $2000.

Figure 2: Example work from a team of three first-year engineering students on a wheelchair ramp project for an individual with ALS (Lou Gehrig’s disease). (Left) Original design submitted to Manor township office and (Right) photograph of nearly completed wheelchair ramp.
6.2) 2003 Wheelchair ramp in Harrisburg city
A second wheelchair ramp was constructed by a team of four students in inner-city Harrisburg in the Fall of 2003. This ramp required engineering ingenuity as the property nearly abutted the sidewalk and road. An access ramp with a flip down final ramp was designed (Figure 3). The access ramp designation allowed a slightly steeper slope as long as the ramp didn’t block the entrance to the house. With collaboration with a city official, the team designed this ramp and nearly completed it. Finishing touches were applied after the semester by a volunteer team from the College.

![Figure 3: (Left) Photograph showing future location of wheelchair ramp (and lack of working space) designed and built by a team of four first-year engineering students for a family with a wheelchair-bound child and grandmother. (Right) The customer (mother) tests the wheelchair ramp as engineering student Jeremy Davis rides in the wheelchair. Railings and sealant were added by a volunteer team from the College following the semester.](image)

6.3) Uncompleted wheelchair ramp in Lancaster City
A third wheelchair ramp project was proposed in Lancaster City in the Fall of 2003. This ramp was proposed for a renter and initially approved by the owner. Lancaster City officials initially refused to allow non-contractors to receive a permit. After some debate and intervention by McBride, Lancaster City officials agreed that regulations allowed unpaid volunteers exemption to contractor licensing and proceeded to review plans. With only two weeks left in the project, city officials finally approved the students’ wheelchair plan, however, the owner subsequently refused to sign-off on the design and requested a new design. After three design iterations with the owner, it became clear that the owner did not want the ramp built, but refused to outright state it. The project was terminated and the students and professors agreed that the project was a valuable (albeit infuriating) experience for the students even without any completed construction. We later learned that volunteer groups that construct wheelchair ramps generally will not consider renters for similar reasons.

6.4) Jigs for life skills in Harrisburg
A group of three engineering students designed and constructed jigs for elementary and high school students with Down’s Syndrome. The jigs teach basic life skills that most of us take for granted, such as where to place a stamp on an envelope, how to fold a paper to place in an envelope, and to hold open baggies to place objects inside. This project required a much lower time commitment than the wheelchair ramps and the project team size was reduced when this
project was reassigned in 2004. The engineering students traveled to the school and met with their customers (the children) two times – once to come up with the design and once to deliver the product and demonstrate its usage. For all students, meeting and working with children with Down’s Syndrome was a new, impressionable, and eye-opening experience.

6.5) Proximity sensors for power wheelchair
This project was offered in 2003, but was not chosen until 2004. The project team of four students designed a proximity sensor for a powered wheelchair for a teenage girl in Lancaster city. The group used a Basic Stamp processor and circuit board to control four sets of sonar sensors. As the wheelchair approaches objects, a speaker sounds an audible alarm that changes frequency and volume based on distance. The entire package was neatly assembled in plastic enclosures and used modular plugs for all sensors (Figure 4). The group designed and built a voltage regulator in order to run the device off the wheelchair battery after 9V battery life was too short. This project, similar to several others, gave a few extraordinary students the opportunity to take on a technically challenging project very early in their education. Another satisfying aspect of the project was several examples of consultation with upper-class computer engineering students outside of class.

![Figure 4: (Left) Proximity sensor for power wheelchair designed and built by a team of four first-year engineering students. Shown are four sets of sonar sensors leading back to main circuitry box. (Next to the circuit box is a 12-Volt battery.) Also shown (Middle) is the original circuit board during testing and (Right) the final product with “cleaned-up” wiring.](image1)

6.6) Ten toy-boxes for single parent families in transitional housing
The toy-box project initially struck us as a borderline engineering project. After all, how much original design goes into a toy-box? While this is true, we were very satisfied with this project. The students obtained a donation of eight sheets of plywood and optimized their design to best fit ten toy-boxes into the eight sheets. Because of good design, they were able to cut and assemble all ten toy-boxes in a single Saturday. We were able to arrange collaboration with students from the Fine Art and Social Work departments to paint the toy-boxes (Figure 5). This was particularly satisfying as one of our first real instances of collaboration with liberal arts departments at the college.
6.7) Dollhouse Projects
We have assigned three dollhouse projects, first in 2003 for the YWCA to use in role-playing for children who were victims of abuse, and two more in 2004 for the YWCA to auction for support of the children’s program. We had hoped that students would design and construct their own dollhouse including wiring and lighting. In each case, however, the students insisted upon buying a kit. Also, in every case, the students were surprised by the time requirement to build a dollhouse. Two of the groups eventually worked an entire weekend straight to finish on time, one group essentially quit in the middle. One group did enter the entire house into CAD, but overall we have been disappointed with the engineering aspect of the project. For the 2004 projects, we arranged for the Occupational Therapy (OT) department to provide students to help with dollhouse decoration and painting. This collaboration never worked out successfully as the engineering groups failed to meet deadlines and left no time for the OT students to work on the project.

6.8) 2004 Wheelchair Ramp in Harrisburg City
Only one team of students signed up for a wheelchair ramp in the Fall of 2004. We specifically listed the height for the wheelchair ramp on the project list and told the students about the length requirement (A 25 inch rise requires a 25 foot long ramp). We assigned six students to the team (one student then dropped the course for unrelated reasons before the project commenced). This group of students set a detailed schedule and met every deadline, working several weekends and evenings. The group faced design challenges of a very small yard and self-imposed challenges to keep owner access to a boarded-up shed and seldom used basement door (see Figure 6). All five members contributed significantly and the project was impressively finished on time. This project struck us as a great example of exceptional students having the opportunity to work on a challenging and rewarding project early in their educational career. We are confident they will think back with pride on their workmanship and accomplishments.
Figure 6: (Left) Sketch, from a team of five first-year engineering students, of a wheelchair ramp that fits in a small backyard and attaches to an existing deck. (Right) Access was allowed off the back of the ramp to an existing shed (top of photograph) and basement door (not pictured – at right of photo behind ramp). Photograph of the ramp is prior to concrete ramp added at base of ramp and auxiliary stairs added off deck.

7. Ending Remarks
The community-based projects have been well-received by the students. Indeed, students were exceptionally responsible, creative, and thorough in their designs, construction, and interactions with customers. The projects have spawned positive interactions within the greater community and with other departments at the College, have provided good publicity for our department, and even garnered a Service Learning award within the College. Students have practiced and developed teamwork, project management, and presentation skills, as well as applied some level of problem solving, design, and basic engineering principles. We feel that the community-based projects have been an excellent addition to our Introduction to Engineering sequence. We encourage professors that Service Learning based engineering projects can be introduced into select courses with positive results and minimal extra work, especially with administrative support in locating project sites.

8. References
2. Engineering Projects in Community Service, Purdue University, http://epics.ecn.purdue.edu/
ASSIGNMENTS AND DATES FOR MAJOR PROJECT

1. Project Statement and Schedule (Due M October 11)
   a. Provide a clear project statement (1 or 2 paragraphs). Define your project, your goals, your timeline, your responsibilities, and who you are working with. In this document, clearly state that you have spoken with your contact and defined the project with that person.
   b. Provide a thorough first schedule, preferably as a Gantt Chart. Be sure to include predecessors and who is doing what. Include design presentation (October 19, but you should have the design done previously to the presentation to the class.) and final presentation. Leave room at the end for writing a short paper and preparing a Powerpoint presentation. You should finish the project by November 19.

2. Main Project Design Presentations (due Tu October 19 or Th October 21)
   Prepare a presentation summarizing your: 1) project, 2) design for the project, 3) approximate timetable for completion, 4) approximate budget. For the presentation, each member of the project will speak for 1-3 minutes and the group will have a maximum of 10 minutes to present. Powerpoint should be used to some extent. In the presentation, you should convince the audience (us and the fellow students) that your design is 1) well thought out, 2) well designed, 3) cost effective, 4) going to be completed by Thanksgiving. Not only should the audience understand and appreciate your design, but they should wish to be a part of your group!

3. Progress Report (due M November 8)
   Provide a one paragraph update on your project and modified Gantt Chart to show your progress and how you will complete on time.

4. Final Presentation (due M November 22)
   Prepare a presentation summarizing your: 1) project, 2) design for the project, 3) construction of project, 4) exact budget. For the presentation, each member of the project will speak for 1-6 minutes and the group will have a maximum of 12 minutes to present. Powerpoint should be used. The presentation should be to a general audience – I will invite the public. Please take digital photographs or bring your actual project for viewing. For general presentation notes, see “Project Presentation Guidelines.doc” in the class folder.

5. Final Report (Report due W November 24 at 5:00 pm.)
   Write a CONCISE paper summarizing your project. For the first page of the paper, put an image of the final project and a short executive summary. The summary should capture the essence of the project. Include the total cost in the executive summary. For the paper, include a detailed budget as either part of the paper or as an Appendix.

Paper should consist of cover page, body, references, and appendix
- Cover page = Executive Summary and “pretty” picture.
- Body of paper. The format is up to you. Adding headings and figures usually makes a technical paper more easily understandable and enjoyable to read. The body of the paper should include a verbal description with multiple figures of the design and final project. If needed,
include justifications and references to demonstrate that you know what you are talking about. The body of the paper need not be long!

- **List of References:** Properly reference the paper.

- **Appendix:**
  1) Parts List and Budget – (List all parts for your project including price and purchase location.)
  2) Any additional information or figures you wish to include. (Permits, Technical drawings, etc.)

*Example page count*

One Page – Cover page; One to Four pages – Body of paper; One to Eight pages – Appendix