Community Outreach for Capstone Design: The Cycle Projects

Craig W. Somerton and Brian S. Thompson
Department of Mechanical Engineering, Michigan State University

Introduction

A current trend in engineering education is the incorporation of a service learning experience. One such example is the EPICS program at Purdue, which involves the volunteer work of engineering students in the community [1]. Another approach, proposed herein, is to utilize the senior capstone design experience in community outreach. This approach has been taken during the past three years in the mechanical engineering senior capstone design course at Michigan State University. Each year a student design team has designed and built a cycle for a youngster with special needs from the local community. These cycles have included a robust three wheel cycle for a large young man (six feet nine, 285 pounds) with a mild form of cerebral palsy, a hand cycle for a double amputee, and a hand cycle for a youngster with little use of her legs. These projects have not only proved to be challenging design projects, but they have also been very rewarding for the students too because they see clearly the benefits of their endeavors. The outreach projects have also impacted the other students in the course and this has developed in them a greater appreciation for the service aspect of being a professional engineer. Further, these projects clearly demonstrate that engineers perform their duties to improve the state of humankind. This function is sometimes obscured when the projects are more detached from the customer.

This paper discusses how these community-based projects were undertaken. It provides the design details of each cycle, as well as additional outreach activities embraced by the student design team. A template is provided to assist other programs in tackling similar endeavors.

Background

The capstone design experience in the mechanical engineering program at Michigan State University is achieved through the course ME 481, Mechanical Engineering Design Projects. This course utilizes industrially sponsored design projects for which the company makes both a financial investment ($3500) and a personnel investment (a staff engineer is assigned to the project). A portion of the financial investment ($600) provides an operating budget for the design team. The remaining funds are used to cover the cost of the design program, for which a significant portion is the cost to put on the end of semester design day. Each team of four students works on the project for the semester under the supervision of a faculty member. During the semester the team makes off-campus oral presentations to the industrial sponsor and provides them with written progress reports. A final oral presentation is made at the department's end-of-semester design day and a final written report is provided to the sponsor. Some projects require the construction of prototypes, and additional funds (beyond the $3500) are provided by the company to cover the development costs. Each year about 160 students enroll in the course, requiring the acquisition of nearly forty design projects, and the projects are typically supervised by thirteen (13) faculty. All faculty participate in this class during a two year period The student grades for the project component of the course are based upon the written reports (graded for technical content by the faculty advisor and English by the department's director of communications), the oral presentations, and a participation grade assigned by the faculty advisor. Though the course is built around the industrially sponsored design project, accommodations have been made for non-industrially sponsored projects. Department policy calls for approval of these projects by the department's undergraduate curriculum committee. The cycle projects all fell under the category of non-industrially sponsored. Additional details concerning the department's design program may be found at http://www.egr.msu.edu/me/ugrad/design/

The theme of prospecting for a community project each academic year began with a letter received by the Dean of the College of Engineering that was forwarded to the coordinator of the ME design program (co-author B.S. Thompson). The letter was from the mother of a disabled young man, Zack. Zack is a large young man (six feet nine, 285 pounds) with a mild form of cerebral palsy. He loves to ride a three wheeled cycle for exercise and he is exhilarated by the freedom it provides him with. Unfortunately, because of his size, the wear and tear on the cycle was significant, consequently several of his cycles had broken due to structural failure. His mother asked for help from the College of Engineering to design a cycle that would be more robust. After discussion with faculty, the design coordinator decided to utilize the project in the ME 481 class. The positive aspects of this decision included providing the students with a challenging design-build-test project, providing the opportunity for the student team to have direct contact with the customer, serving the community, and providing an opportunity for a very positive public relations activity. The negatives of going forward with such a project include the significant effort required to build a final product (not just a prototype) would go well beyond the effort required for a standard industrially sponsored project; the potential for failure of a high-visibility project; and the lack of adequate funding support. The barrier of the effort level and potential failure was overcome by finding students that were genuinely excited about the project and securing excellent support for the manufacturing phase through the department’s technician and the college's machine shop. Funding was provided from the budget of the design program, and this was minimized by soliciting for donations of materials and parts.

Zack’s bike proved to be a tremendous success. Zack was provided with a robust cycle that he is still using some three years later. The student design team felt that they had an exceptional education experience. There was excellent and very positive media coverage of the project that has greatly enhanced the public image of the department’s design program. The design program occasionally receives letters from residents of Zack’s community, Ionia, MI, praising the program for its accomplishment. With these successes, the design coordinator decided that each year the program should undertake such a community service project. For each of the last two years, middle school teachers that participate in an outreach component of the design program have approached the design coordinator about building a cycle for a disabled youngster attending their schools. This has lead to a cycle for Andrew in Okemos, MI and a cycle for Korbi in Holt, MI. Both of these cycles were hand-operated cycles. The design details of each cycle is provided below. It must be noted that the success of these projects is due in large part to the commitment of the student team, whose membership is provided in Table 1.

Table 1. Cycle Projects Student Design Teams

Zack's Bike	A Cycle for Andrew	Korbi's Cycle
Rob Farley	Jeremy Dalrymple	Molly DesJardins
Lynn Figore	Andy Fedewa	Drew Reichenbach
Nick Sadowski	Aaron Freudigman	Julie Richards
Tim Tapert	Katie Sutherland	Quentin Welch

Zack's Bike

A picture of Zack's bike is shown in Figure 1. In the design synthesis stage, the team came up with several design alternatives. Because of Zack's physical limitations all of the alternatives were three wheel cycles. The alternatives included a custom design that would be built from scratch and six commercial models. A design decision matrix using the twenty two design parameters suggested by Thompson[2] lead to the Worksman Executive Trike as the design choice. With this choice the design team still had two major obstacles: the first was whether to use a traditional seat design or a recumbent seat design. And the second was whether to replace the Workman's front suspension fork with an RST suspension fork or a modified motor-bike suspension fork. Once again with the assistance of design decision matrices, the team decided to adjust the regular seat on the Workman Executive Trike rather than adapt it with a recumbent seat. Also the current front fork of the Workman's would be swapped out with a Rock-Shox mountain bike front suspension fork rather than swapped out with a modified motor-bike suspension fork.

Figure 1. Zack's Bike

Numerous computer and mathematical methods were used in evaluating the design ideas and developing the final design. Computer analysis included selecting materials through the

Cambridge Material Selector package, dynamic modeling through Working Model and MathCAD, stability estimates using Excel spreadsheets, and validation using static finite element analysis. The final design called for the purchase of a Workman Executive Trike that would then have five major structural modifications. The first of these modifications extended the rear axle from 21 inches to 31 inches, in order to increase the stability of the bike. The second modification raised the bike frame four inches to add extra support to the seat post. To further support Zack and reduce the bending moment created with the frame being raised four inches, the third modification was the addition of a back support. The fourth modification was an added support beam, while the fifth modification was the replacement of the standard fork with a Rock-Shox mountain bike front suspension fork.

The manufacturing of the final design involved the disassembly of the standard Workman Executive Trike and interfaces were created in the frame at the locations required to accommodate the five structural modifications. The department's technician performed the welding required for the structural modifications. The bike was then reassembled and painted to Zack's specifications. With a completed bike, testing was conducted with Zack as the test pilot and the bike was found to perform admirably. The bike was presented to Zack on design day with considerable media coverage from local television and newspapers.

A Cycle for Andrew

A picture of the cycle for Andrew is shown in Fig. 2. As can be seen from the machines anatomy this is a hand cycle, due to the fact that Andrew had his legs amputated as a baby due to severe burns. He also has some scarring on his arms and upper body that has decreased both his upper body strength and mobility. He was identified by a teacher at his middle school who participates in the outreach portion of the department's design day. Because of his physical condition Andrew was not able to go bike riding with his friends, so that the goal of this project was to provide Andrew with a human-powered vehicle that will enable him to participate in this activity.

Figure 2. A Cycle for Andrew

Initially the team considered three possible design alternatives. The first was to purchase one of the many commercially-available hand cycles and customize it for Andrew's condition. This alternative proved to be too costly. Second, the team considered buying a frame from one of the commercial manufacturers, and then building and appending the remaining components. This proved to be very untimely, as there was a three-month delivery time, and the commercial manufacturers showed little interest in selling only the frame of their cycles. The design alternative chosen was to build the cycle from the ground up. In designing the cycle from scratch, the team focused on the design of four main components: braking system, drive train, steering, and frame. For each component, design alternatives were generated and a decision matrix approach was used to determine the best. The following decisions were made for each component:

Braking System: Standard bicycle calipers
Drive Train: Offset chain and sprocket with synchronized pedals
Steering: Hand steering
Frame: Custom designed and built frame using rectangular tubing

With these decisions made, the team turned its attention to gathering the required materials. One team member arranged for the donation of the tubing for the frame. The University's Department of Parking and Public Safety allowed the team to select several bicycles from its impound yard that were scavenged for several of the required components.

Manufacturing took place in the college's machine shop facility and proceeded much in the same fashion as Zack's bike. When completed, Andrew thoroughly tested the cycle. This lead to several minor modifications, including eliminating the largest gear on the top cassette, adding a protective guard over the top gear cassette, and replacing two nylon pulleys, that showed significant wear, with sprockets from a bicycle derailleur.

One important aspect of this project was an outreach component to Andrew's middle school home room. Three times the team made presentations to this class of approximately sixty (60) students. The middle school students were engaged by the team and the project, and even participated in some of the design decisions. Our sense was that this activity showed engineering in a very positive light to the middle school students and most probably opened many of them up to this as a career opportunity. Furthermore the eclectic nature of the project provided a unifying theme woven through the fabric of an apparently unrelated middle-school curriculum. The eighth graders were provided with a panoramic educational vista. This observation was shared by their teachers.

This project had good media coverage including an early morning radio interview with the faculty advisor and Andrew. The local community newspaper covered the project, and one of the local television stations was present at design day and had a segment on their evening broadcast.

Korbi's Cycle

The hand cycle that was designed and built for Korbi is shown in Fig. 4. Korbi, pictured in Fig. 4, was an eighth grader at the time of this project, and was identified for the design program by the technology teacher at her middle school who participates in the department's design day activities. Due to a disease, Korbi has very limited use of her legs (they produce little force and cannot be extended farther than 30 degrees from vertical), and she also has difficulty balancing. The design process followed by the team was very similar to the previous two projects, except that the team decided to build a prototype to test several design alternatives. This proved to be extremely useful, because it gave the team the opportunity to physically explore many design options. The final cycle has a custom frame made from chromoly-steel aero tube that greatly enhanced the aesthetics over the rectangular tubing used in Andrew's cycle. A first class bicycle was bought at cost from a local bicycle shop from which several components were scavenged, including the front fork, crank mechanism, seat, front and real wheels, and the derailleur. The team developed a CAD drawing for the frame to ensure sizes and fit. The manufacturing of both the prototype and final product was performed in the college's machine shop. The painting was done at a local auto body shop without charge.

The cycle was presented to Korbi at the department's design day and was covered by the local media. A half page article on the project appeared in the city's newspaper and one local television station broadcast a segment on the project.

Figure 4. Korbi's Cycle

Thus the design program has completed three projects for pre-college students from three different communities. These projects have garnered numerous accolades and these successes have motivated the faculty to continue these outreach activities.

Guidelines for Implementing Cycle Projects

Based on our experiences with these three cycle design projects, we suggest the following guidelines as a framework for their implementation.

Identifying a Customer: Certainly identifying a youngster who would benefit from a custom cycle is key to the success of these projects. Faculty contacts in the community can play a role in this prospecting and identification process. Religious groups, sports clubs, and other affiliations are all potential sources. Reaching out to local middle school or high school teachers, counselors, or principals can also lead to potential customers.

Selecting a Student Team: The number one criterion in selection of students is their commitment to the project and their work ethic. It is extremely useful for some of the team to have strong machining skills. An experience in cycling has also proven to be useful. Finally, experience in finite element analysis will assist in the design analysis.

Team Supervision: It is critical to have a faculty member supervising the project. Since these projects can take on a high profile, the faculty role is to keep the team on target and facilitate issues with the machine shop, university administration, the customer and the customer's family, the media, and any outreach activities. It is mandatory that a weekly meeting with the team and the faculty advisor be held, and that during the construction phase the faculty advisor make frequent trips to the machine shop to assess progress.

Customer's Family Involvement: These projects have been much more successful when the whole family of the customer, mom, dad, and child, has been intimately involved with the engineering students and has been supportive of the project. This is an important consideration in the selection of the customer. The challenges confronting the child, from a parent's perspective, complement those perceived by the child.

Evaluation of Customer’s Physical Abilities and Social Context: One of the first tasks that must be undertaken by the design team is an evaluation of the customer's physical abilities. This ensures that a viable design specification is established. Parents, doctors, and physical therapists have all been utilized to provide this information. It is also important to get a sense of the social context in which the customer will be riding the cycle, and to find out what social pressures and expectations there might be.

Budget: A budget of approximately $1000 is needed for the materials and cycle accessories (chains, brakes, helmet, etc.). The team should be strongly encouraged to minimize expenditures through donations or discounts of materials and cycle accessories from local bike shops. These off-campus interactions involving commercial activities are another valuable experience for students. One of our design teams created a professional poster on the project recognizing such contributions that was displayed at design day.

Machine Shop Facilities and Technician Support: To enhance the educational experience of the design team and to control costs it is essential for the team to have access to a high quality machine shop facility, including welding facilities, for the manufacturing of the cycle. Arrangements need to be made to allow the team access to the shop beyond the normal 8-5 working hours to accommodate schedule conflicts associated with other classes. Though it is expected that the team will do much of the manufacturing themselves, technician support to perform functions that the team is not qualified to undertake, such as welding, must be available. For these functions, the team works directly with the technician and orally communicates required design information.

Engineering Outreach: These projects provide excellent outreach opportunities to high schools and middle schools concerning a career in engineering. The design team can make their presentations to a class at the middle school or high school of the customer, and even involve the class in the design process through participation in a brainstorming session or in evaluating design alternatives. These presentations have been wholeheartedly welcomed by teachers and school principals. It has been our experience that this outreach is most effective when the customer's own class is involved. However, one does need to be sensitive to the customer's comfort-level in interacting with their classmates about their disability.

Societal Outreach: Presentations to pre-college students by college seniors provide several other functions too. First, these engineering students serve as role models. Youngsters observe that females can indeed become engineers (thus, in the team selection stage, a mixed gender group should be created); contrary to the popular misconception that the field is only for the male. Secondly, the engineering students provide reinforcement to youngsters to continue their education beyond high school at the university level. And thirdly, the pre-college students obtain a glimpse and a realization of why they are studying mathematics, physics, CAD, health education, communication, creative writing, etc. All of theses eclectic disciplines are being utilized and integrated by the engineering students in the creation and delivery of the cycle.

Media Coverage: Local newspapers, television and radio stations need to be contacted and invited to attend a presentation of the cycle to the customer. The faculty advisor may want to issue a press release and utilize the college's and university's public relations offices. It is interesting that we have never received any coverage from the campus newspaper!

Conclusions and Recommendations

Over the past three years, three cycle design projects have been completed in the capstone design course. They have proved to be challenging technical projects encompassing nearly all of the conventional components of a design-build-test project: synthesis, analysis, ergonomics, manufacturing, customer satisfaction. Beyond the technical challenges, these projects have allowed the students to develop a personal relationship with the customer and they have graduated with the conviction that they have made a significant difference in the quality of life of another human being. Furthermore, the projects have provided some excellent outreach opportunities to middle school students, demonstrating what mechanical engineering is all about and, hopefully, recruiting some into the profession. Finally, these projects have provided excellent public relations material for the design program, the department, and also the university.

References

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Author Biographies

CRAIG W. SOMERTON

Craig W. Somerton is an Associate Professor of Mechanical Engineering at Michigan State University. He teaches in the area of thermal engineering including thermodynamics, heat transfer, and thermal design. Dr. Somerton has research interests in computer design of thermal systems, transport phenomena in porous media, and application of continuous quality improvement principles to engineering education. He received his B.S. in 1976, his M.S. in 1979, and his Ph.D. in 1982, all in engineering from UCLA.

BRIAN S. THOMPSON

Brian S. Thompson is a Professor of Mechanical Engineering at Michigan State University. Currently he serves as the Departmental Design Coordinator. Dr. Thompson has published in the following areas: mechanisms, smart materials, composite materials, flexible fixturing, robotics, variational methods and finite element techniques. He received a BSc and MSc from Newcastle University, England, in 1972 and 1973 respectively, and a Ph.D. from the University of Dundee in Scotland in 1976.