Integrating Service-Oriented Design Projects in the Engineering Curriculum

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Abstract
Engineering curricula are undergoing continual advancements. Faculty seek to apply new techniques and strategies to interest students, to address their diverse backgrounds, and to achieve a balance between theory and practical, hands-on applications. One area of advancement is project-centered education. To provide students with realistic applications, projects are being used as an instructional vehicle. The extent of the projects depends on the type of course, ranging from support projects in analytical courses to backbone projects in design courses. No matter where a course falls in this range, a key question in project-centered curricula is the type of projects that should be used. In this paper, we propose a service-oriented strategy for choosing projects. This strategy provides a number of advantages to students and faculty. These advantages are described in the context of basic implementation principles and four case studies. Results are shown for an undergraduate design methods course, an undergraduate capstone design course, two graduate-level product development courses, and a Masters of Science research project.

Introduction
Project-centered education is becoming an emphasis of many engineering curricula. As part of this emphasis, unique opportunities exist to expose our students to a variety of design or open-ended projects. Service projects, or those that emphasize human need, represent one such opportunity. According to the NSPE Engineers' Creed, Professional Engineers are called upon to "place service before profit … and the public welfare above all other considerations." In this spirit, it is possible to create successful service projects that directly benefit a number of groups in our society: those marginalized by disasters, persons with disabilities, and the rural poor of developing countries. In the US, nearly 10% of the population copes with a severe disability[1]. Worldwide, many national economies have led to lifestyles with persons struggling for physical survival on a daily basis. A coarse measure of the distribution of technology indicates one-third of our world's population lacks access to electricity[2]. Engineering curricula should acknowledge these abundant opportunities for service-oriented design projects in our increasingly global society, and seek reliable methods for delivering and realizing such projects with our students.

This paper presents four approaches exemplifying the integration of human need projects into student design work. These approaches are: (1) an undergraduate design methods class in which teams design new concepts, such as a heat exchanger for medical relief teams; (2) an undergraduate capstone design class in which students deliver a working prototype, such as a wheelchair positioning unit; (3) two graduate prototyping classes in which students deliver a working prototype, such as an assistive lock-opener for persons with physical disabilities; and (4) an MS thesis research program for developing countries, with such projects as a handbook for

selecting small-scale electricity generation technologies for use in remote areas. These approaches provide a framework for how "service-oriented design projects" can be implemented in an engineering curriculum. Four elements common to each of these approaches are: (1) a source of project ideas; (2) funding; (3) tools such as design techniques and prototyping facilities; and (4) deliverables with a service impact.

Benefits of service oriented design projects include intense student enthusiasm, a scope realizable as student projects, and broadening engineering horizons into international and philanthropic concerns. These projects address multiple ABET outcomes and produce deliverables serving those in need of medical relief, persons with disabilities, and the rural poor of developing countries. We present this framework using examples[*] from three US universities: The University of Texas (UT) at Austin, Brigham Young University, and University of Missouri-Rolla.

Case Study 1: Undergraduate Design Methods Class

A mechanical engineering design methods course at UT Austin includes the conceptual design of human-need projects. One month of the course is dedicated to producing a conceptual design by teams of three to five students. Teams select a project from descriptions provided by the instructor. Students employ the design methods[3] taught in the course to generate conceptual designs, and then select the most promising for fulfilling the customer needs. The conceptual designs include drawings showing geometry and materials, and a bill of materials with cost estimates. Only limited prototyping and experimentation are conducted by the teams, so no funding beyond the normal course fee structure is required.

The faculty and teaching assistants for the design methods class generate project ideas from personal experiences or contacts. Examples of previous projects include automatic pitching machines and pasta cookers. Other, service-oriented projects, such as a device for assisting people with disabilities in labeling envelopes, are obtained from local school districts, service organizations, and personal contacts. A teaching assistant, through contact with a medical relief organization, identified one such project with a service-oriented component. The project was for medical teams that make semi-annual trips into rural Mexico and establish a temporary clinic, hospital, and operating room. The design opportunity was to capture the waste heat from the exhaust of a 5kW diesel generator and use it to heat water for cooking, bathing, and medical purposes. Constraints from the relief workers included strict limitations on weight, volume, cost, and complexity.

Although the "waste heat water heater" project was only one out of five choices, approximately half of the student design teams selected the project. The unusually high interest resulted from a combination of the potential for implementation with a real customer, and the human need aspect. The high level of student interest and motivation also led to an unusual number of additional questions concerning constraints. The fact that the project originated as a need from an actual customer seemed to prompt the students to design for reality, rather than making assumptions for the sake of convenience.

[*] Syllabi available: http://madlab.me.utexas.edu/~mgreen/documents/service-oriented_syllabi.pdf

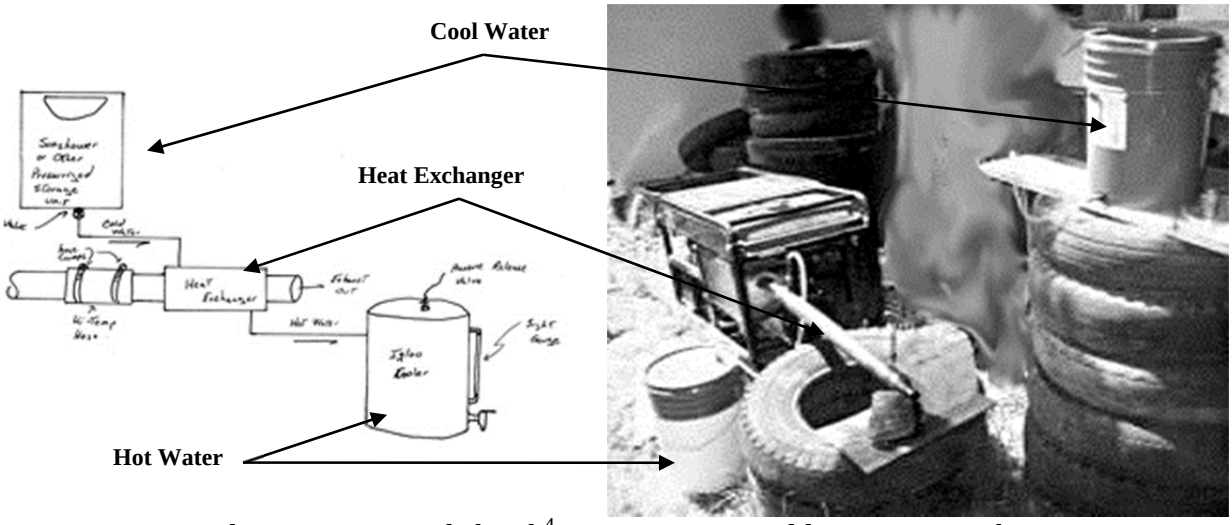

Figure 1: Water heater conceptual sketch[4]. Figure 2: Field-testing water heater prototype.

When the course was completed, the conceptual design reports were passed on to a graduate student for potential implementation. This student coordinated final design, prototyping, and field-testing of the device as a personal project. During a two-week operation in rural Mexico, the $50 device heated 5 gallons per hour of tap water to 150°F[5]. The prototype was light, small, and simple to operate and maintain.

Undergraduate Design Methods Class (UT Austin)

Project Source	Local school districts, service organizations, and personal contacts
Funding	Normal course fee structure
Tools	Design methods, Traditional engineering analysis
Deliverables	Culminates in conceptual design. Finalization and prototyping possible w/ outside work by graduate students.

Case Study 2: Undergraduate Capstone Design Class[6]

Brigham Young University (BYU) in Provo, Utah has included projects that address human need in their undergraduate capstone design course. The capstone course at BYU is a two-semester course in which student design teams, typically composed of five senior engineering students, design a product to satisfy the requirements of a project sponsor. Capstone projects generally include the design of a product as well as the construction of a working prototype. Most capstone projects are sponsored by industrial partners of the university. These industrial partners provide a liaison engineer for the student design team as well as a financial contribution to the capstone program. The cost structure of the capstone program is designed to accommodate a few "non-paying" projects each year.

Capstone projects that address human need are identified through potential sponsors, without active solicitation. These projects are either supported by an outside sponsor or else they fall into the "non-paying" category mentioned above. These projects can be either for an individual or for an organization. The student design team interacts directly with the individual or the organization in developing design solutions and a prototype. A student machine shop and wood shop are available for the construction of prototypes.

Design projects that address human need, including a multi-function wheelchair table and a tricycle merry-go-round for children with physical challenges, have been completed in the BYU course. A product that is currently being developed in the course is a mechanism for picking up and storing a wheelchair behind the seat of an extended-cab truck. The product will allow the driver with disabilities to enjoy greater independence by providing a means for loading the wheelchair in the truck without assistance from another person. The scope of the project fits well within the criteria for a capstone project and allows for both design and construction of a prototype.

Kurt Fackrell, a member of the student design team for the "wheelchair storing" device, noted two aspects of the project that are different from many other capstone projects. First, the project is for an individual, rather than for a corporation. The student design team interacts directly with the end user of the product, rather than with an assigned liaison engineer from a company. Second, the project involves every aspect of the design, rather than just a component of a larger system. The students will follow the project all the way from preliminary design concepts to installation of the final product into the truck.

Mr. Fackrell noted that, "*…working personally with the end-user has been very rewarding, especially when that user will gain so much from the project result. We have extra incentive to build a device that will serve beyond his expectations for years to come.*"[7] The incentive and satisfaction that come to students who are involved in such "human need" projects provide additional motivation for including such projects in the engineering curriculum.

The administrators of the capstone course at BYU plan to continue providing projects that address human need, although no formal structure has been established for soliciting such projects. A new center on campus called the Jacobsen Service Learning Center[8] has been established for identifying service-related opportunities for the university. This center has been identified as a potential source for additional project ideas for the capstone course.

Undergraduate Capstone Design Class (BYU)

Project Source	Capstone sponsors (individuals or organizations), service-learning center
Funding	Outside sponsor or covered by capstone projects budget
Tools	Design methods, Prototyping shop
Deliverables	Working prototypes delivered to customer

Case Study 3a: Graduate Design Course with Assistive Technology Products

At the University of Missouri-Rolla (UMR), assistive devices serve as the design projects for a graduate course: Modern Product Design. The goals of this course are to educate students in some recent research findings in the discipline of design as well as promote the engineering ideals of service to the community. The one semester course enrolls between 15 and 25. One aspect of special interest in the course is teaching the graduate students how to apply a "new" design principle or idea. To ensure students understand the material in a practical and applicable context, student teams design and develop fully functioning and usable prototypes. The critical challenge and learning in this course comes as students apply the design principles to their design projects. Topical coverage consists largely of recent research results from the design community along with basic approaches to product design. Since the majority of the course introduces new design research results, the previous scope of research applications is generally

limited and perhaps not directly focused on product design. Creativity and innovation are required on the part of the students to apply a "new" idea, which is a critical aspect of an advanced technical education. In essence, the goal is not to teach the students something that is known, but to teach them how to extend current knowledge to a point where they can use it for the problem at hand.

The design projects are developed in cooperation with Rolla Public Schools Special Services Program. Our goal is to develop products that improve the educational climate of students with disabilities. Example products range from mobility assisting devices for students to educational assistive devices for teaching a specific skill or lesson to products that enhance the teacher's ability to control the classroom or prepare lessons more easily. In general, any product that helps is an acceptable design project.

In Fall 2000, three products were developed in the Modern Product Design class. One product assists teachers in teaching children to walk up and down stairs. Another product facilitates the teaching of fine motor skills such as ringing doorbells and manipulating latches. The third device moves students in a swinging motion, a twisting motion, or both to aid in calming students with autism.

In each case, the graduate students begin the product design by visiting the schools, interviewing students and teachers, and developing a focused set of customer needs. As the course progresses, students move through the basic stages of design; starting with clarification, conceptualization, and embodiment; and ending with fabrication of a usable prototype. One emphasis of the course is to explore new methods in concept generation. Figure 3 shows concepts for the swinging product that were generated using a method focused on developing modular product architecture[9].

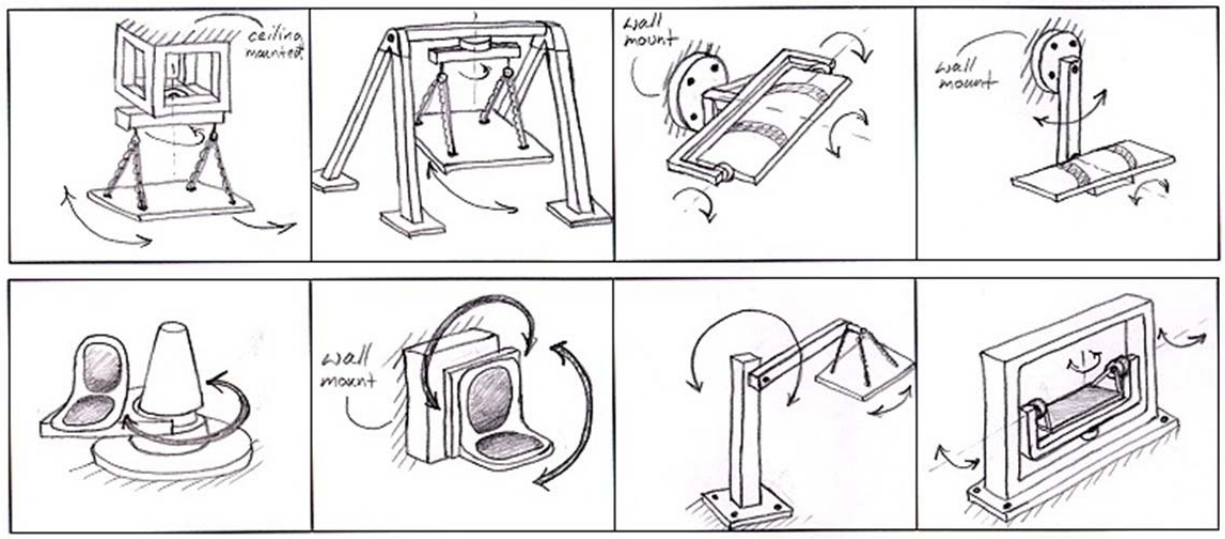

Figure 3: Concept sketches for a product to swing and rotate a student.

Shown in Figure 4 is the completed stair-step training product. In response to the teacher's need for compact storage, the steps stack inside the next taller step. The stacked steps store in the

center section when not in use. The stair step trainer also features removable PVC railings to decrease storage space, and locking casters stabilize the stairs during stair step training.

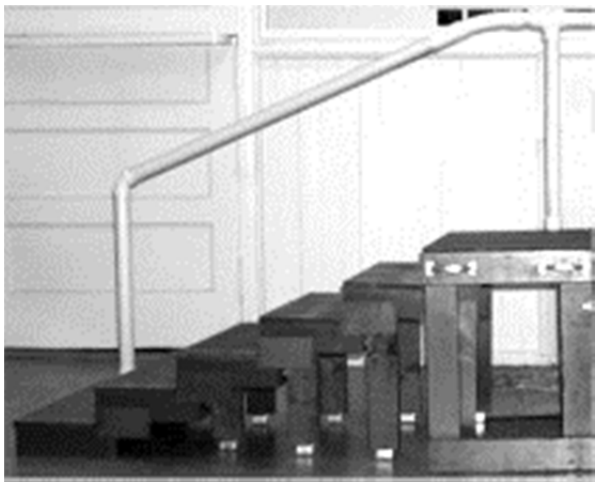

Figure 4: Stair step trainer product.

Figure 5: Activity board left view.

Figure 5 shows the final activity center prototype used to assist in the development of fine motor skills. The activity center has different activity modules that can be changed to feature different activities. One activity, for example, is used to train students to remove nuts from bolts. Training modules not in use are stored in the back of the activity center. The primary surface is curved to increase access to multiple activity modules for users who have limited reach and difficulty moving. The module mounting positions on the sides of the activity center enable simultaneous usage by three students.

To this point, the Modern Product Design course has been a significant success for the students of Rolla Public Schools, graduate students at UMR, and as outreach for the University of Missouri-Rolla. The activity center product won a RESNA award, the projects were featured in an article in the local daily newspaper, and the products are still in use at Rolla Public School campuses.

Graduate student sentiment on how the class could be improved echoes the needs of engineering design. In general, the graduate students felt better characterization and quality of customer needs, both in specificity and breadth, would have improved the projects. Also some technology, resource or method to reduce prototype effort and time would have allowed more time to have been spent on conceptualization and design analysis.

Graduate Design Methods Class (UMR)

Project Source	Rolla Public Schools, Individuals
Funding	University outreach support
Tools	Basic woodworking and hand tools with some rapid prototyping equipment
Deliverables	Working prototypes delivered to customer

Case Study 3b: Graduate Product Design and Prototyping Class

The graduate Product Design and Prototyping class at UT Austin culminates with students delivering fully functional prototypes to local "customers" with physical disabilities. The basis

of this course is product design, development, and prototyping. Product design projects are the focus of the student efforts, with emphasis on functional, working designs as opposed to the common ink-paper concepts. Students must produce a working, tested, and robust design by the end of a semester, delivering the result to the customer. This focus provides graduate students from mechanical engineering, electrical engineering, social work, and special education with a unique opportunity to work with hardware, in contrast to the theoretical focus of most graduate-level courses. Thus, the intent of the course is to produce functional designs based on real product/humanitarian needs.

Projects are selected which require the novel synthesis of low to medium technology (not high technology), and involve $100-$300 of funding. Projects for initial offerings of the course were solicited from facilities that include persons with disabilities: the Austin State School and two local school districts. Interdisciplinary design teams of 4-5 graduate students from engineering, social work, and special education are formed using team selection algorithms[10] based on MBTI, Six Hats, and technical/hands-on skills. The teams work with supervisors, teachers, and the students (customers) at the schools to refine project ideas into electromechanical design problems related to the customers' occupations and learning environments. These projects present a unique challenge to the design teams in that most of the problems admit solutions that provide assistive technologies for the tasks currently performed by the customers. Table 1 shows examples of projects completed since the course's inception.

Table 1: Examples of design projects for persons with disabilities.

- Assistive bowling device
- Visual phone interface for deaf persons
- Device to wrap baking potatoes in foil using only one hand
- Switch activated ball thrower
- Key actuation device for persons with limited strength and range of motion
- Letter labeler to assist persons with disabilities on a job site
- Sand-bagging system to assist persons with disabilities on a job site
- Electro-mechanical can crushing system
- Sensory-stimulation system for persons with disabilities
- Décor chip sorter to assist persons with disabilities on a job site
- Accessible shelving system for persons with disabilities

Each week of the course employs a unique balance of one lecture, one lab or reverse engineering exercise, and one experiential presentation. Every class week begins with a lecture on a design method[11], assistive technology, or social work topic. The mid-week class includes a hands-on activity such as reverse engineering a product using a discussed design method, or completing a prototype construction lab to learn the use of fabrication equipment. The last session of each week is devoted to an experiential presentation wherein students are given a 10x10 ft^2 section of a wall to post team identity, background research, or project results. The instructors and other teams review the presentations and provide interactive feedback on the progress of the designs. In the last class meeting of the semester, students lead a feedback session that emphasizes critical and complimentary feedback for student progress.

After initial project choices and visits to their customer locations in Austin, the students systematically follow the product development process[12] taught in the class. Design teams produce a proof-of-concept, an alpha, and a beta prototype at key milestones. Up to 25 students

a semester utilize a prototyping shop including over $40,000 in fabrication equipment (Figure 6). Students are required to develop a package at the end of the semester that will be delivered to the customer. This package includes a working device or system that satisfies the customer needs, a brief report documenting the project results and chronological decisions, a Bill-of-Materials, an illustrated manufacturing plan, and a brief user's manual. Each team also submits a 3-page article and a 5-minute videotape to the annual Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) international student design competition[13]. Since 1994, twelve teams from UT Austin have been selected to present their designs at the annual RESNA conference.

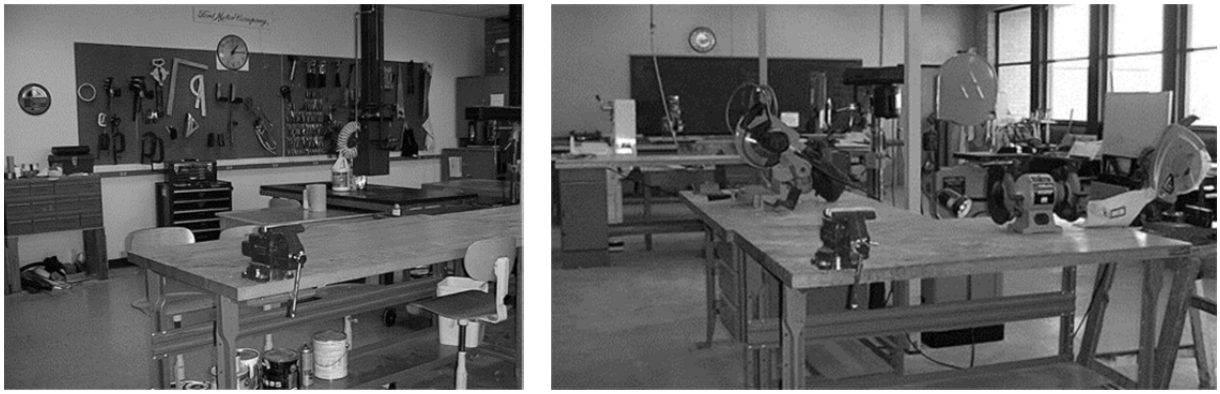

Figure 6: UT Austin Mechanical Engineering prototyping lab and cutting shop[+].

For illustration, Figure 7 and Figure 8 show two RESNA winners that are currently in use in Austin schools. The assistive bowling project focused on the design of a bowling device that would allow people, especially children, with disabilities to bowl with more autonomy and normalization than current wheelchair bowling ramps offer. The innovative design enhanced accessibility for children with many types of disabilities and greatly increased the performance of the bowling ball ramp. The adaptive key handler (Figure 8) allows a wheel-chair user with severely limited strength and range of motion to use key-operated elevators and doors. The device was designed to be compact, portable and lightweight for use by an 11-year-old student with rheumatoid arthritis. His use of a wheelchair requires riding the elevator to attend classes.

[+] Sponsored by Ford Motor Company, National Instruments, the Keck Foundation, and Flour-Daniel.

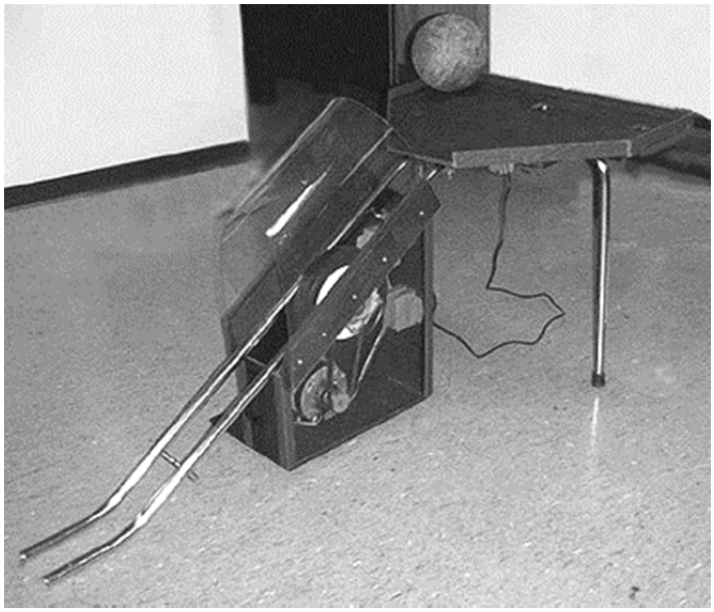

Figure 7: Assistive bowling device[14].

Figure 8: Assistive key handler[15].

Graduate Product Design and Prototyping Class (UT Austin)

Project Source	Local schools with students that have special needs
Funding	Foundation funding, endowment funding, and course fees
Tools	Design methods, Traditional engineering methods, Prototyping lab
Deliverables	Working prototype and manufacturing plan

Case Study 4: MS Thesis Research Program

Design research for use in developing countries has been integrated into graduate research at UT Austin. One such project culminated in a manual for selecting small-scale power generation technologies for use in remote areas. In this case, the student was specifically motivated to apply the principles of engineering design to needs of the rural poor in developing countries. Support for the graduate student was elicited from teaching assistantships and competitive fellowships. The research began with a hit-and-miss search of literature and organizations to uncover information and potential topics. Some of the most useful sources of literature were Non-Government Organizations[16,17] (NGO's), and hard-to-find literature was accessed through archival works[18,19] focused on developing countries. Travel to various NGO's was interspersed throughout the research to access physical libraries and consult with development experts.

The literature search and consultation with NGO's guided the selection of the topic, "Small-Scale Electricity Generation: Selecting an Appropriate Technology". The student wrote the thesis[20] as a manual minimizing technical terms in order to be "understandable to those who lacked engineering training, but not capability." The manual guides the reader through a seven-step selection methodology[*] for choosing among solar, wind, hydro, fossil-fuel generators, and utility grid extension.

[*] The steps are: understand the technologies, gather site resource data, assess the amount of power needed, estimate costs of viable options, select a technology, specify and install the system, and monitor and document performance..

The choice to develop a methodology for selecting among available technologies, as opposed to refining a single technology, was important for at least two reasons. First, it allowed the student to gain familiarity with multiple options to address a prevalent need. This type of expertise is often more in demand for applications in developing countries than specialization in a single solution. A common sentiment expressed by development workers is, "… what we need is not another new technology, but a resource for making an appropriate selection from what is already available." Secondly, a small research budget with no fieldwork possibilities was more conducive to developing a selection methodology rather than incremental development of a specific technology.

Effectively disseminating this type of research poses a challenging problem[21]. The approach taken in this case was to make the selection manual available for download[22] and pursue a non-profit publisher to provide a paper edition. Raising awareness of the research results among the target audience will include publicizing the work through contacts with NGO's and placing how-to articles in relevant periodicals.

MS Thesis Research Program (UT Austin)

Project Source	Literature review, NGO's
Funding	TA appointments, Competitive fellowships
Tools	Design methods, Non-traditional literature base
Deliverables	Publication of how-to manual

Benefits of Service-Oriented Projects

It is widely accepted that design projects address multiple ABET outcomes. The previous case studies, for example, include: the application of engineering knowledge, utilizing experimentation, designing systems, solving engineering problems, and communicating effectively. Achievement of these educational objectives is amplified by the student enthusiasm often accompanying a service-learning component. Service-oriented projects can serve those in need of medical relief, persons with disabilities, and the rural poor of developing countries. This leads to a high level of student motivation that facilitates educational objectives, particularly when students have direct customer contact. The motivating power of the student-customer connection in human need projects is apparent in a recent student's comments: "*Academic design exercises seemed so irrelevant; what difference did it make whether our design report was an order of magnitude off? The [UT Austin] prototyping class changed that. After we played with the kids and talked with their therapist, we knew we had to deliver a working product. We just couldn't disappoint them.*"

In addition to high student motivation, service-oriented projects provide other positive characteristics. They often provide a satisfying closure within the constraints of the academic calendar. A well-scoped project allows students to experience a complete product development cycle, from gathering customer needs to delivering a functioning prototype. Additionally, service-learning offers opportunities to broaden engineering education into a "global and societal context[23]," exposing students and faculty to new outlets to pursue humanitarian interests through research and career opportunities.

Principles of Implementation

The previous examples serve as case studies illustrating how "service-oriented design projects" can be implemented in an engineering curriculum, and highlight four necessary elements: (1) a source of project ideas, (2) funding, (3) tools such as design techniques and prototyping facilities, and (4) deliverables with a service impact. Table 2 suggests possible sources of service-oriented design projects, such as local schools or international design competitions. Funding is often a minor issue, since the low cost nature of many service projects allows integration into an existing design course with little or no addition to the existing course fee structure. In some of the previous examples, small amounts of funding were obtained through project sponsors. The existence of tools such as a prototyping facility is a more difficult issue, and projects must be designed to be realizable with the available facilities. Finally, there are numerous ways design projects can have a service impact. Conceptual designs can be passed on for prototyping and implementation, working prototypes may be delivered to the customer, or how-to manuals can be written and distributed. In the case studies above, integrating service-oriented design projects into the curriculum has proved richly rewarding to students, "customers", and faculty.

Table 2: Sources of service-oriented design projects.

- Local Resources
  - Local schools with special needs
  - Needs personally known to faculty and students
- Service-Learning
  - Books on the implementation of service-learning[24]
  - Websites of service-learning projects[25,26]
- Design competitions
  - Rehabilitation Engineering Society (RESNA) www.resna.org
  - Basic Utility Vehicle competition www.buv.org
  - Society Competitions, such as the 2001 ASME sip-and-puff[27]
- Technologies for Developing Countries
  - Development by Design www.thinkcycle.org/tc-topics/
  - Development technology unit www.eng.warwick.ac.uk/DTU/

Bibliography

[1] McNeil, John M. Americans with Disabilities: 1991-92. Data from the Survey of Income and Program Participation. U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census. Accessed Oct. 2001. http://codi.buffalo.edu/graph_based/.demographics/.awd/AWD/Type.html

[2] "Providing Energy Needs for Two Billion People," New Release No. 97/1313S, World Bank, Accessed Mar. 2002. www.worldbank.org/html/extdr/extme/1313.htm

[3] Otto, K. N. and Wood, K. L., Product Design, Prentice-Hall, Inc., NJ, 2001.

[4] Shimek, M., Holland, W., Kan, C., Rollins, J., Sanchez, C., "The Cleaners Project 2: `Waste Heat' Water Heater," ME 366J Conceptual Design Report, Dept. of Mechanical Engineering, The University of Texas, April 10, 2000.

[5] "Field Test of a Waste Heat Water Heater Prototype," Accessed Jan. 2002. http://madlab.me.utexas.edu/~mgreen/water_heater

[6] Communication with Robert Todd, professor of mechanical engineering, Brigham Young University, Dec. 2001.

[7] Communication with Kurt Fackrell, member of the student design team, Brigham Young University, Jan. 2002.

[8] www.byu.edu/jacobsencenter/findex.htm

[9] Stone, R., Wood, K., and Crawford, R., "A Heuristic Method for Identifying Modules for Product Architectures," *Design Studies* 21(1):5-31, 2000.

[10] Jensen, D.L., and Wood, K.L., 2000, "Incorporating Learning Styles to Enhance Mechanical Engineering Curricula by Restructuring Courses, Increasing Hands-on Activities, & Improving Team Dynamics," Proceedings of the 2000 ASME International Mechanical Engineering Congress and Expo., November 5-10, Orlando, Florida.

[11] Otto, K. N. and Wood, K. L., Product Design, Prentice-Hall, Inc., NJ, 2001.

[12] Otto, K. N. and Wood, K. L., Product Design, Prentice-Hall, Inc., NJ, 2001.

[13] "Rehabilitation Engineering and Assistive Technology Society of North America," www.resna.org

[14] Cox, D., Koshti, S., Jackson, B., Malish, A., Numan, M., Shipley, D., "Design of an Assistive Bowling Device," *Proceedings of the RESNA Annual Conference*, Summer 1999.

[15] Shimek, M., Van Wie, M., Kothawade, S., Subrahmanyam, R., Escobar, M., "An Assistive Technology Key Turning Device For Independent Entryway Access," *Proceedings of the RESNA Annual Conference*, Reno, Summer 2001.

[16] Intermediate Technology Development Group (ITDG) Homepage, Rugby, UK. www.itdg.org and www.developmentbookshop.com

[17] Educational Concerns for Hunger Organization (ECHO) Homepage, Ft. Myers, FL. www.echonet.org

[18] "Appropriate Technology Library," Available for purchase on-line. Accessed Jan. 2002. www.villageearth.org/atnetwork

[19] "Humanity Development Library 2.0," Humanity Libraries Project, Accessed Jan. 2002. www.humanitylibraries.net

[20] Green, M. G., "Small-Scale Electricity Generation: Selecting an Appropriate Technology," Masters' Thesis, Dept. of Mechanical Engineering, The University of Texas, Dec. 2001. http://madlab.me.utexas.edu/~mgreen/research

[21] Green, M. G. "Publishing Engineering Research on Appropriate Technology," Dec. 2001. http://madlab.me.utexas.edu/~mgreen/research

[22] Green, M. G., "How to Generate Electricity in Remote Areas – A Simple Guide to Choosing the Right Technology," Version 1.0. Feb. 2002. http://madlab.me.utexas.edu/~mgreen/seg/

[23] ABET. "Criteria For Accrediting Engineering Programs Effective for Evaluations During the 2001-2002 Accreditation Cycle," Engineering Accreditation Commission of the Accreditation Board of Engineering and Technology, 2000. www.abet.org

[24] Tsang, E., Projects That Matter: Concepts and Models for Service-Learning in Engineering, American Association for Higher Education, 2001. Preview: www.aage.org/service/series_new.htm

[25] "101 Ideas For Combining Service and Learning," Accessed Mar. 2002. www.fiu.edu/~time4chg/Library/ideas.html.

[26] National Service-Learning Clearinghouse Homepage. Accessed Mar. 2002. www.servicelearning.org

[27] "Student Design Contest Index" American Society of Mechanical Engineers. Accessed Jan. 2002. www.asme.org/students/Competitions/designcontest/index.html

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