AC 2008-961: ENGINEERING SENIOR DESIGN PROJECTS TO AID INDIVIDUALS WITH DISABILITIES

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Engineering Senior Design Projects to Aid Individuals with Disabilities

Abstract

This paper describes the experience of the Department of Mechanical Engineering (ME) at The University of Toledo (UT) during the past fourteen years in introducing engineering students to Assistive Technology. This is done during the course of the ME Senior Design projects when students custom design devices for individuals in the community with physical disabilities. The goal of these projects is to assist individuals with disabilities so they can enjoy life and realize their maximum potential. Furthermore, these projects significantly enrich the education of engineering students through the experience of designing and building devices to meet a real need; students also get feedback on how well the device satisfies that need. These projects are aimed at designing and constructing devices that will allow disabled individuals to improve the quality of their life without suffering from the associated financial burdens. Accomplishing these projects also provides support for an educational infrastructure that allows students to enhance their understanding of physiological, environmental, and biomechanical factors that influence aimed at enhancing quality of life. Students also have the opportunity to present their products to their peers—most of these projects are presented by students at local, national and international ASME (American Society of Mechanical Engineers) and RESNA (Rehabilitation Engineering Society of North America) meetings—and to publish their work in peer-reviewed publications. Finally, these projects also provide the ME Department with an opportunity to offer a unique service to the local community.

Description of the Senior Design Course in the Mechanical Engineering Department:

The catalog description of the ME Senior Design course is provided in the 2006-2008 catalog of the University as follows[1]:

> *"Students work in teams using knowledge gained in earlier courses to solve real design, manufacturing, and operational problems relevant to industry. Oral and written communications with participating companies, as well as teamwork, are stressed. Other topics include patents, product liability, safety, ethics, and design for manufacturing."*

<u>Class meetings, participation, and role of Course Director and Project Technical Advisor:</u>

One faculty member serves as Course Director and is in charge of all administrative aspects of the course, including identifying the projects to be conducted by the students. Each group is supervised by a Faculty Advisor (Project Technical Advisor) and a Client Advisor. The Project Technical Advisor and the Client Advisor meet with their groups on a weekly basis.

Activities during the class meetings may typically include lectures and guest lectures on topics such as the design process, creativity, product liability, patents, and the business world. The frequency of the class meetings is determined by the Course Director. Attendance is taken at the beginning of each class period. Part of the grade is determined by attendance. Students are responsible for all materials, announcements, schedule and grading policy changes discussed in class.

Organization of Senior Design Projects:

1. Project Identification:

Senior Design projects are typically proposed by local industries, faculty and students. Each project is supervised by one or more faculty advisor and possibly an industrial contact. Each prospective project is presented to the class in a brief (about 5 to 10 minutes) presentation by the client or Faculty Advisor during the first class meeting. Each class member submits a list of his first, second and third choices by the end of the first week of class. Requests are submitted to the Course Director, who assigns students to projects considering, insofar as possible, student preferences. Project groups are typically selected with 3-4 group members.

2. Group Formation:

Each student group selects a Group Leader, a Technical Liaison, and a Purchasing Agent. Each group member must: i) accept responsibility for completing his/her assignments on time and in a professional manner, and ii) recognize that the quality of his/her work and each group member's work affects the total group performance, and, hence, group grade. The Group Leader's duties include: i) scheduling and coordinating meetings, and ii) coordinating assignment responsibilities (that is, when group members can not agree, the leader must decide). The Technical Liaison communicates with the technician and machinist, when appropriate. The Purchasing Agent is responsible of all purchasing aspects of the project. The project technical advisor meets with his group on a regular scheduled weekly basis.

3. Project Proposal

Each group prepares a project proposal in consultation with their project Faculty Advisor. The proposal should include i) project objectives, ii) a description of the methods to be employed, iii), the responsibilities of each of the group members, iv) a timetable indicating when each step is to be accomplished, and v) a proposed budget for the project.

The project proposal is to be developed as a clear written document signed by the Faculty Advisor with a copy submitted to the Course Director by the end of the third week of the semester. The project proposal is presented orally to the class during the fourth week of the semester.

4. Design Phase:

Beginning the fourth week, each group must submit brief written weekly progress reports summarizing their activities and the results obtained. These progress reports should be signed by each group member and the Faculty Advisor. For the midterm, each group prepares a detailed report on the status of their project and makes an oral presentation summarizing the progress made and discussing the challenges and successes.

5. Implementation Phase:

Starting the tenth week, each group implements its design recommendations by i) constructing and testing a prototype, ii) implementing a test program to collect needed design data, or iii) continuing analysis to include software development, etc. During this phase, each group will develop a task list and schedule for the completion of the project. Some of the tasks may involve ordering parts and scheduling work with the department machine shop. Only the Technical Liaison contacts the department machine shop, and only the Purchasing Agent contacts the department budget coordinator for all ordering and material pick-up.

Students cannot order any materials before having a budget approved by both the Faculty Advisor and the Course Director. Each project purchase must be approved by the Faculty Advisor or the Course Director prior to release of an order. A *Senior Design Projects order form* must be used to purchase any item. This form is available on the web and must be approved by both the Faculty Advisor and the Course Director the first time an order is placed. Students cannot exceed their approved budget and are not generally allowed to purchase or order material using their own funds.

A final written report and a web page are due in class on the last day of classes. A standard engineering report format includes a) a cover sheet, b) an abstract (executive summary), c) an introduction (should include a statement of objectives, as well as salient information to bring the reader up to speed), d) the body of the report: methods, analysis, results, etc., e) conclusions, and f) appendices (such as: calculations, data tables, computer programs, etc.). Each group will present its design report orally. Each of these presentations (approx. 15 minutes) is scheduled during the final examination week. Every group member must participate in this oral presentation. Additionally, a design exposition is planned during the final examination week. Participation is mandatory in both of these events.

6. Grading:

Letter grades are assigned at the successful completion of the course objectives. Grading consists of two components: group (same grade for each group member) and individual (distinct grade for each individual). Each group member will be required to submit an evaluation of all his partners. This evaluation will be used in determining both peer and supervisor ratings.

Senior Design Projects to Aid Individuals with Disabilities:

One of the overall purposes of the National Science Foundation (NSF) Act of 1950 is to promote and advance national health through its engineering programs. The NSF provided a mechanism in 1988, through the Bioengineering and Research to Aid the Disabled (BRAD) program of the Emerging Engineering Technologies Division and subsequently the Biomedical Engineering and Research to Aid Persons with Disabilities (BME/RAPD) programs of the Division of Bioengineering and Environmental Systems (BES), to encourage student engineers at US universities to design and build devices for persons with disabilities[2]. The principal goals for this project are aimed at training undergraduate mechanical engineering students in applied bioengineering design, and to improve the quality of life for disabled individuals, which is in accordance with some of the stated objectives of the BME/RAPD programs [2].

Currently, about 20 universities in the country receive funding from the RAPD program to support undergraduate engineering Senior Design projects directed to aid individuals with disabilities. Our University is one of those funded universities. These Senior Design projects consist of the design and fabrication of custom built devices for physically challenged individuals. These projects are conducted in collaboration with an agency in town that is dedicated to promoting independent living, and they result in the design and construction of devices that will assist disabled individuals to better enjoy life and realize their maximum potential without suffering from the associated financial burdens. Written reports on the completed projects are submitted for annual publication in the yearly NSF book for Engineering Senior Design Projects to Aid Persons with Disabilities. Also, an annual report that includes a description of the completed projects is provided by the Principal Investigator by July 1 of each grant year.

With support from the NSF since 1993, 91 undergraduate senior projects have been successfully completed and implemented by ME students at our University. These projects involved 385 senior engineering students, as summarized in Table 1.

Table 1 Senior Design projects directed to aid individuals with disabilities conducted in the ME department at the University of Toledo

Academic Year	# of completed projects	# of students involved
1993-1994	5	14
1994-1995	5	20
1995-1996	4	18
1996-1997	5	27
1997-1998	7	32
1998-1999	3	11
2000-2001	9	36
2001-2002	9	37
2002-2003	11	51
2003-2004	10	40
2004-2005	8	32
2005-2006	4	25
2006-2007	7	27
2007-2008*	4	15
Award Duration	91	385

* During 2007-2008, four projects were successfully completed during the fall semester. Four projects are currently being conducted during the spring 2008 semester.

These Senior Design projects accomplish the following objectives:

1) They provide persons with disabilities with devices designed to improve their quality of life.

2) They provide opportunities for engineering students at UT to enhance their understanding of physiological, psychological, environmental, and biomechanical factors that influence the design of products aimed at enhancing quality of life for disabled individuals. This will also enrich the students' education by providing them with the opportunity to design and build a device that meets a real need.

3) They provide engineering students at our University with an opportunity to offer a unique service to the local community.

These projects are described in our University's chapter in each of the 1994-1998 and the 2001-2006 editions of the annual NSF publication[3-13] entitled: "Engineering Senior Design Projects to Aid the Disabled." Also, several refereed journal and conference papers[14-27] resulted from these activities and were co-authored by the students and the supervising faculty.

The eleven (11) projects successfully completed during the 02 - 03 AY were:

Project #	Title
1	Manual Racing Wheelchair
2	Modification of a Manual Racing Wheelchair
3	Riding Lawn Mower Adaptation
4	Motorized Fishing Rod and Reel
5	Beach Wheelchair (2nd generation)
6	Hot and Cold Water Dispenser
7	Sledge Hockey Sled
8	Adaptation of a Power Wheelchair for Cardiovascular Enhancement
9	Adaptation of a Power Wheelchair to Enable Leg Exercise
10	Wheelchair Lift for Mobile Home Access
11	Adapting a Van Driver Seat for Uneven Seating Conditions

The ten (10) projects successfully completed during the 03 - 04 AY were:

Project #	Title
1	An Arcing Lift System that Allows a Wheelchair User to Access his Home from his Garage Independently
2	A Scissor Lift to Transfer a Wheelchair User to and from the Deck of a Pool
3	Adaptation of a Wheelchair with a Camera Support System
4	Mechanical Valve to Drain a Leg Storage Bag

5	Bathtub Transfer System
6	Adaptation of a Wheelchair to Support a Harmonic Storage Unit
7	Air Rifle Trigger Release Mechanism
8	Adaptation of a Wheelchair with a Laptop Tray
9	Computer Cabinet with a Telescoping Monitor Arm
10	Adapted Archery Equipment

The eight (8) projects successfully completed during the 04 - 05 AY were:

Project #	Title
1	Vehicle Carrier for a Recumbent Trike
2	All-Terrain Wheelchair for Use in MetroParks
3	Adaptation of a Walker with a Removable Tray to Carry Belongings
4	Tandem Ice Hockey/Recreation Skate
5	Aiming Device and Stand
6	Camera Stand Assembly for a Wheelchair User
7	Extension Push Handles for a Manual Wheelchair User
8	Pool Wheelchair for Recreational Pool

The four (4) projects successfully completed during the 05 - 06 AY were:

Project #	Title
1	Portable Mount to Access Crutches
2	Adaptive Hand Tool to Promote Independent Living
3	Independent Transfer Lift
4	All Terrain Wheelchair for MetroParks – 2nd generation

The seven (7) projects successfully completed during the 06-07 AY were:

Project #	Title
1	Adaptation of a Wheelchair with a Painting Stand
2	Wheelchair Lifting System for a PT Cruiser
3	Development of a Device for Attaching a Wheelchair to A Shopping Cart or a Baby Stroller
4	Adaptation of a Walker to Carry Belongings: 2nd Generation
5	Development of a Seat Back Cleaner and an Ergonomic Groom

6	Improving Workplace Ergonomics for an Individual with Disabilities
7	Wheelchair Accessible Passive Leg Exerciser Unit

The four (4) projects successfully completed during the fall 2007 semester were:

Project #	Title
1	Development of a Beach Wheelchair for the Ability Center.
2	Adaptation of Piano Pedals for a Music Instructor Using a Wheelchair.
3	Development of a Device to Assist an Individual to Buckle his Car Seat Belt.
4	The development of a racing wheelchair for a college student.

The four (4) projects in progress during the spring 2008 semester were:

Project #	Title
1	The Development of a Device to Assist a College Student with Very Limited Motor Control to Buckle his Car Seat Belt.
2	The Development of a Sit-to-Stand Wheelchair
3	Adaptation of a Wheelchair with a Camera Support System for a College Student.
4	A Hospital Bed that Would Lift a Person Up.

Broader Impacts of the Senior Design Projects to Aid Individuals with Disabilities:

The objective of the grant awarded by the NSF to our University is to support the Senior Design projects performed by undergraduate engineering students. These projects consist of the design and fabrication of custom-built devices for physically challenged individuals. These projects, as they did in the past fifteen (15) years, will help and impact disabled peoples within the local community. At the same time, these projects increase the collaboration between our University and different rehabilitation units in the community. At the end of each semester, an exposition is organized to display the prototypes and students give final presentations. This exposition is attended by community leaders, health care providers' representatives, patients and their families, high school teachers, members of local professional societies, and our University community. External referees judge the final presentations and monetary awards are presented to the best projects. The outreach of these projects includes contributions within the discipline, contributions to other disciplines, contributions to education and human resources, and contributions beyond science and engineering.

Contributions and impact within the discipline:
These projects will have the following impact:
1) Helping the engineering needs of the local Ability Center (our partner)

2) Impacting the educational infrastructure by allowing students to enhance their understanding of physiological, environmental, psychological, and biomechanical factors that influence the design of products that aimed at enhancing quality of life for disabled individuals.
3) Enhancing the education of engineering students by providing them with the opportunity to design and build a device that meets a real need.

<u>Contributions and impact to other disciplines:</u>
These projects will have the following impact:

1) Impacting the special needs community to contribute to an educational process that they normally would not be aware of.
2) Impacting the health care providers by providing a fertile atmosphere with an organized setting to solicit and carry out projects in a very positive way.
3) Allowing disabled individuals participation in recreational activities that they may not have been able to get involved in.

<u>Contributions and impact to education and human resources:</u>
At the end of each semester, an exposition is organized to display the prototypes designed and built by the engineering students. This exposition is attended by community leaders, high school teachers, patients and their families, and the University community. These activities provide exposure to science and technology for pre-college teachers, young people, and other non-scientist members of the public.

<u>Contributions and impact beyond science and engineering:</u>
These projects will help and impact disabled people within the local community by providing them with devices that are designed to improve their quality of life at no cost. The outreach and impact of these projects include:

1) Allowing the viewing audience in television, radio and newspaper to know what is going on at the University in relation to the types of projects being conducted to aid people with disabilities.
2) Allowing the viewing audience to know what types of services are provided within the community to aid people with disabilities.
3) Allowing the viewing audience to see what difference an educational experience can be when community, hospitals and universities work hand in hand.

Examples of successful projects:

In what follows we present two representative projects. The first one is a typical mechanical engineering project, while the second one is an interdisciplinary project that combined mechanical and electrical aspects.

<u>Project 1: Development of a compact and mobile scissor lift to transfer a wheelchair user to and from the deck of a pool</u>[18]

This project was conducted during the fall 2003 semester and four students were involved: Josh Manuel, Phil Clement, Erik Pakulski and Robert Godiciu. A seventeen-year-old female with C6 tetraplegia is a competitive swimmer. She has good use of her upper arms, little use of her lower arms and hands, and no use of her trunk and legs. This individual practices at a swimming pool three to five times a week, which requires her to get from her wheelchair to the deck of the pool so she can get into the water. Her previous transfer system was very dangerous and stressful, as she transferred manually from her wheelchair to an intermediate step approximately half way between the seat height and floor. That procedure required the assistance of another person, which is why the client wants to move from her wheelchair to the pool independently and as comfortably as possible.

At that time, no specific product was available on the market for this type of situation. Seat lifts are available on the market; however, such devices are primarily used in assisting an individual out of a chair and are directed toward the elderly. Since the client has absolutely no use of her legs, this device would be useless in this application. Another option would be the use of a scissor-lift mechanism, which is primarily used in construction applications. However, those scissor lifts on the market deal with large applications and loads; and they are heavy, cumbersome and expensive. Since no commercial item fits the needs of the client, it was necessary to develop a small, compact scissor lift to raise and lower her from the height of a wheelchair seat to the deck of a pool and vice-versa.

The design requirements were specified by the client as follows: the unit must be stable on wet surfaces, easily setup independently by the client, durable and rust-proof, the seating must not be slippery or irritating to the skin, and the unit should be lightweight for transportation. The initial design was an automated system that would have a scissor lift frame powered by locking gas charged springs, a linear actuator, or hydraulic cylinders. A switch or lever arm within reach of the client would activate any one of these motion generation mechanisms. This design would allow minimal effort to be exerted by the client to operate the system and would provide great stability. A House-of-Quality approach was used to evaluate the different methods of powering the scissor lift. The linear actuator was found to be the best choice. Aluminum framing was used with a cloth seat.

As shown in figure 1, the unit includes a lower frame and an upper frame. Both frames were made from 1" diameter round aluminum with 1/8" wall thickness. Cross members were added to provide stability. They were attached to linear slides that were connected to the upper and lower frames. One linear actuator was attached to the fixed lower frame and the moving upper frame. As it extends, the cross members slide along the upper and lower frames and the upper frame rises. Two twelve-volt rechargeable batteries were used to power the linear actuator. The batteries were attached to the lower frame and were wired to a toggle switch within reach of the user. The linear actuator was rated to provide 1,350 lbs of force to lift 250 lbs.

The dimensions of the unit are 19" from the seat to the floor, 15" wide and 20" deep. The lower frame is elevated 4" from the floor. To facilitate the transportation, two 24-inch wheels were attached to the rear of the unit, and two small wheelchair caster wheels were added to the front. To provide a stable unit during transfer, locking brakes were added to the rear wheels of the unit. The brakes were activated by a single lever within the reach of the client.

Machining and several parts were donated by Invacare Corp. The unit was tested by the client, as shown in figure 2. It was found stable. Transfer to and from the unit was easy and comfortable. The unit itself functions fully as a manual wheelchair and as a powered lifting

device. The unit can be easily disassembled for storage. For this purpose, the seat is moved to the lower position and the wheels are removed. The scissor lift can be picked up and rolled away. Total cost of parts and supplies was $1,300.00. The students designed a web page that describes this project that can be found at the following URL address:
http://www.eng.utoledo.edu/mime/design_clinic/design_expo/Fall03Pages/2003-04-06/home.htm

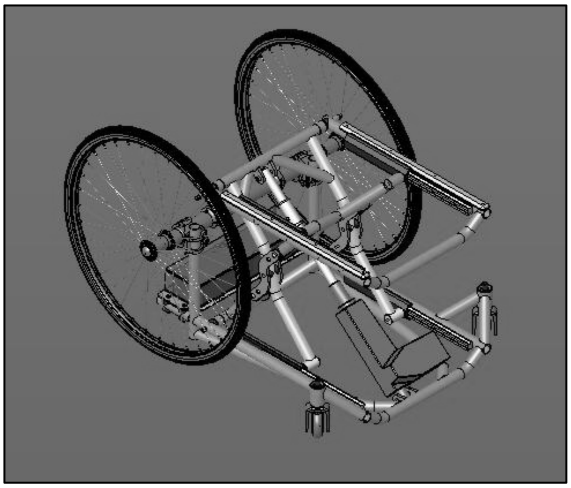

Figure 1 CAD drawing of the unit

Figure 2 This picture shows the unit being tested

Project 2: Development of a vertical wheelchair platform lift for home access[20]

This project was conducted during the fall 2000 semester and five students were involved in this project: Susanne Bellante, Eric Stevens, Tully Esterline, Anthony Vonderembse and Kurt Knapke. This project involved the design and construction of a vertical wheelchair platform lift to be used by a paraplegic man with limited use of his arms. The individual used to enter and exit his home using a long ramp in front of the house. This was inconvenient and unsafe for him and his family: he could not easily exit his home during the winter when the ramp is covered with snow and ice, and he would be at risk if the ramp would ever be inaccessible during a fire or other disaster. The objective of the project was thus to safely lift this physically challenged individual fourteen inches from the garage floor to the house level.

Five methods of driving the lift were investigated, which included using a hydraulics system, linear actuators, scissor lifts, a wench and pulley system, and power screws. A dual linear actuator system using a matrix approach was selected based on several design criteria: a smooth and independent operation, platform height, design simplicity, safety, and costs. The design parameters included the platform size, the weight to be lifted, and the amount of travel of the lift.

The platform size needed to be large enough to fit the wheelchair, leaving extra room for the client's arms as he turned the wheels to enter and exit the lift. The rear wheels of the client's wheelchair were 32 inches apart. Allowing for ample room for the client's arms as well as the switch box, the platform was designed to be 42 inches across. The weight of the individual, his motorized scooter, the platform and its holding frame was estimated as 500 lbs (2224 N). A design load of 1,000 lbs (4448 N) was used to ensure a minimum safety factor of 2. The amount of travel of the lift was 14 inches, the height of the step between his garage and his home. Also, the platform height at the lowered position could not exceed two inches from the ground to allow the client to easily roll himself onto the platform. Since the individual would operate the lift independently, the design must allow him to roll onto the platform using a forward motion from either the garage or his home.

The system, shown in figure 3, consisted of two main parts: a part that moved up and down along a fixed part: the outer frame. The platform and its inner holding frame formed the moving part. Steel rectangular tubing was used for constructing both frames. All pinch points on the lift were enclosed to prevent injury and enhance aesthetics.

The linear actuators were attached to the holding frame and the fixed outer frame, as shown in figure 4; they were wired to a capacitor and connected to a power source using a regular 110-volt wall outlet. The wire routing and electrical boxes were mounted to move up and down with the inner frame so that the only wire that would tighten during travel would be the extension cord to the wall outlet.

Structural analysis was conducted on the inner holding frame to determine the maximum stresses using finite element analysis software, namely SDRC I-DEAS. Total cost of parts and supplies was $1,200.00. The students designed a web page that describes this project and can be found at the following URL address:
http://www.eng.utoledo.edu/mime/design_clinic/design_expo/fall00pages/2000-01-06/home.html

Figure 3 Vertical Wheelchair Platform Lift

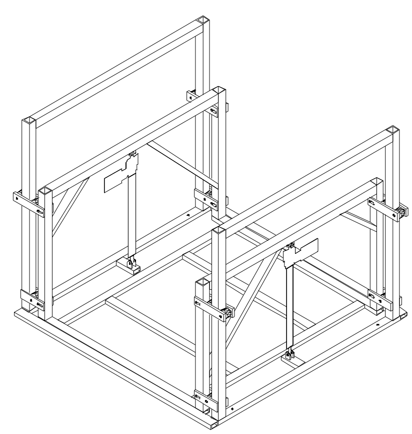

Figure 4 Isometric Schematic of the Vertical Wheelchair Platform Lift

Outcomes of the Senior Design Course in the Mechanical Engineering Department:

The ME Senior Design course is the capstone event of undergraduate education. Each project is designed to address several of the "a-k" ABET evaluation criteria for engineering programs (Table 2). The course outcomes are listed in Table 3.

Table 2 ABET a-k evaluation criteria

The ABET a-k evaluation criteria are[28]:

a. Ability to apply knowledge of mathematics (including differential equations and statistics), science and engineering.
b. Ability to design and conduct experiments, as well as make measurements on and interpret data.
c. Ability to design a system, component, or process to meet a desired need.
d. Ability to function in multi-disciplinary teams.
e. Ability to identify, formulate, and solve engineering problems.
f. Understanding of professional and ethical responsibility.
g. Ability to communicate effectively.
h. Broad education necessary to understand the impact of engineering solutions in a global/societal context.
i. Recognition of the need for, and ability to, engage in life-long learning.
j. Knowledge of contemporary issues.
k. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

Table 3 The course outcomes

The course outcomes include the ability to:

1. Work in self-directed teams.
2. Communicate work to others.
3. Create product specifications based on customer needs while recognizing environmental, economic and societal factors.
4. Perform a design of a system or product based on product specifications.
5. Generate design alternatives.
6. Evaluate design alternatives using both analytical approaches and engineering judgment.
7. Use engineering software packages in design activities.
8. Build a prototype within a specified time period and within a budget.
9. Test a prototype and compare its performance to design specifications.
10. Understand the ethical responsibility of an engineer in design.

Assessment of outcome achievements:

An achievement of course outcomes is tested through instructor evaluation and student questionnaires followed by faculty focus group assessment. For a course to be considered assessed, the instructor, students and focus group must have tested and evaluated achievement of at least 75% of the course outcomes. Because of the variation in grading schemes by different faculty, the acceptable achievement level in each course outcome is set by each instructor, and the level is reviewed and discussed when the focus groups performs the actual assessment. To assess their perception of the level of course outcome achievement, students rate their achievement of the course outcomes based on a scale: 1 = excellent, 2 = high level, 3 = adequate level, 4 = below adequate, 5 = none or not covered. The acceptable level for the achievement of course outcomes is 3. Based on data from the student questionnaires and instructor's evaluation, each course outcome is rated as achieved, not achieved or not assessed by the focus group assigned to assess the course. The metric goal is 1 for achieved, 0 for not achieved and NA for not assessed.

Each course outcome is then mapped to one or more of the (a-k) program outcomes with the basic premise being that achieving the course outcomes contributes to the achievement of the (a-k) program outcomes. The assessment method, then, is based on the measurement of the levels of achievement of course outcomes, which are then mapped to achievement of the (a-k) outcomes.

During fall 2004 and spring 2005 semesters, 41 and 42 students were enrolled in the ME Senior Design class, respectively. During this academic year, 32 students were involved in 8 projects to aid individuals with disabilities. The remaining 51 students were involved in industrial funded projects. Usually, about 50% of the students enrolled in the class participate in the assistive technology projects. Table 4 summarizes the methods used to determine if course outcomes were achieved during the academic year 2004-2005.

Table 4 Methods used to determine if the Senior Design course outcomes were achieved

Course Outcome	Method of Assessment	Assessment Document	Level of achievement				
			Spring 2005		Fall 2004		Accepta-ble level
			Avg.	Std. Dev.	Avg.	Std. Dev.	
Outcome # 1	Peer evaluations; progress reports	Midterm peer evaluations	88.7%	12.7%	92.9%	10.7%	80%
		Final peer evaluations	87.3%	19.2%	86.9%	20.9%	80%
		Progress Reports	98.3%	5.4%	95.4%	6.1%	80%
Outcome # 2	Oral individual and group presentations	Group oral presentation of proposal	92.2%	3.8%	92.7%	4.4%	80%
		Individual oral presentation of proposal	89.4%	4%	90.6%	5%	80%
		Group Midterm oral presentation	95.1%	4.8%	93.7%	4.5%	80%
		Individual midterm oral presentation	94%	5.8%	93%	5.7%	80%
		Group final oral presentations	92.6%	3.0%	95.2%	2.3%	80%

		Individual final oral presentations	92%	3.0%	95%	3.7%	80%
Outcome # 3	Midterm report and final report	Midterm report	88.2%	5.9%	93.2%	5.4%	80%
		Final Report	90.0%	6.4%	93.1%	7.7%	80%
Outcome # 4	Midterm report and final report	Midterm report	88.2%	5.9%	93.2%	5.4%	80%
		Final Report	90.0%	6.4%	93.1%	7.7%	80%
Outcome # 5	Proposal and Midterm report	Proposal	88.9%	6.2%	90.9%	12.8%	80%
		Midterm report	88.2%	5.9%	93.2%	5.4%	80%
Outcome # 6	Proposal and Midterm report	Proposal	88.9%	6.2%	90.9%	12.8%	80%
		Midterm report	88.2%	5.9%	93.2%	5.4%	80%
Outcome # 7	Final Report	Final Report	90.0%	6.4%	93.1%	7.7%	80%
Outcome # 8	Final Prototype	Final Prototype	94.3%	4.6%	75%	33.2%	75%
Outcome # 9	Final Prototype	Final Prototype	94.3%	4.6%	75%	33.2%	75%
Outcome # 10	Not assessed						

Table 4 indicates that outcome # 10 related to understanding the ethical responsibility of an engineer in design was not assessed quantitatively. We plan to use the Value-Sensitive Design (VSD) approach to systematically integrate ethics into the senior design projects. In the VSD methodology, conceptual, empirical and technical issues related to a particular design are investigated[29]. Specific human values that have ethical significance will be considered in the design process such as privacy, human welfare, informed consent, usability, among other values. The VSD approach allows incorporating ethical concerns in the design process with clear objectives and goals.

The results of the assessment of this Senior Design course that are mapped to the (a-k) program outcomes for these two semesters are shown in Table 5. This Table shows the (a-k) program outcomes across the top. Each program outcome is subdivided into three columns labeled Ok, No and NA for the number of outcomes that were achieved, not achieved or not assessed, respectively. The focus groups decided if a course outcome had been achieved primarily based on the student evaluations being less than 3 and the class average exceeding or being equal to the minimum value given by the instructor. In addition to columns for each outcome, there is an additional column labeled 75% of course outcomes assessed. It is possible that a single course outcome covers material for multiple (a-k) outcomes. For this Senior Design course, and for the two semesters discussed above, there were six multiple (a-k) outcomes that the course outcomes addressed.

Table 5 Achievement of Senior Design course outcomes for fall 2004 and spring 2005 semesters

	A			B			C			D			E			F		
	Ok	No	NA	Ok	No	NA	Ok	No	NA	Ok	No	NA	Ok	No	NA	Ok	No	NA
Spring 05	2			1			3			1			2			1		1
Fall 04	2			1			3			1			2			1		1

	G			H			I			J			K			75% of course outcomes assessed
	Ok	No	NA	Ok	No	NA	Ok	No	NA	Ok	No	NA	Ok	No	NA	
Spring 05	2			1						1			1			Yes
Fall 04	2			1						1			1			Yes

Conclusions

Since 1988, the National Science Foundation has funded the Bioengineering Research to Aid the Disabled (BRAD) Program. This program has supported The University of Toledo (UT) for the last fifteen years. Over 90 projects were conducted to aid quadriplegics, paraplegics, and people with different disabilities within the greater Toledo area. The projects promoted increased involvement of UT with the area community, contributing to an increase in media coverage, on and off campus. These projects also increased collaboration between UT and various medical institutions in the area. So far, the UT projects have successfully achieved the three stated goals of the BRAD program: (1) to provide people with disabilities engineered devices to improve their quality of life; (2) to enhance the education of student engineers; and (3) to allow universities opportunities for unique service to their local communities.

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