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JRRD Guest Editorial

Master of engineering program in biomedical engineering at Cornell University: Collaboration with external sponsors to prove concepts in assistive devices

As a biomedical engineer, one seldom gets the opportunity to help patients return to health in areas in which the magnitude of the need, or the adoption of the approach, is unproven. Returning to my alma mater, Cornell University in Ithaca, New York, in late 2004, I was given the opportunity to coordinate the master of engineering program in biomedical engineering. Teaching students about the biomedical engineering arts and the Food and Drug Administration environment, and using projects proposed by external companies and physicians, we began to build a new Department of Biomedical Engineering.

Professor Michael Shuler, our chairman, has had a distinguished career in chemical engineering. After a long process, he established a new program in biomedical engineering as part of the College of Engineering. The scientific orientation for the department is to understand disease mechanisms from a "molecules-to-man" perspective. Our engineering strategy was to develop a 1-year master of engineering program with an engineering project as the focal experience. Real projects are a demanding first experience and permit an engineering student to learn four key dimensions: How to—

1. Understand customer needs.
2. Reduce needs to a concept and design.
3. Fabricate and test the design.
4. Deliver a documented prototype that can be reproduced.

As the Program Coordinator, I solicit student-appropriate projects from sponsors that are presented to the students each year. Most projects are with my Cornell colleagues in their respective research laboratories. The remainder are with external sponsors. Early on, I realized we needed an exemption from University policy concerning intellectual property. With help from corporate and foundation relations in the College, we were permitted an exemption, primarily because our master of engineering students are not employees and pay full tuition for our program.

External sponsors have been companies and individual physicians hoping to develop a prototype of a clinical concept. Remarkably, several of these have been in assistive technologies and surgical systems, including—

- A lower-cost stroke rehabilitation system.
- An assisted walker.
- A blink restoration device.

Clients pay no fee for work performed on the project, but we do ask for reimbursement of direct expenses, such as student travel, etc.

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STROKE REHABILITATION SYSTEM

Bruce T. Volpe, Professor of Neurology & Neuroscience from the Burke Rehabilitation Hospital in White Plains, New York, came to Ithaca to present a seminar (to our master of engineering students) on his work with Neville Hogan and H. I. Krebs on a robotic system for stroke rehabilitation that had remarkable results. After the seminar, we discussed a concept for a portable and lightweight system that could be used on a kitchen table as an alternative to his Massachusetts Institute of Technology-Weill Robot. With the help and laboratory space provided by Professor Andy Ruina, Professor of Mechanics in Mechanical Engineering, four enthusiastic students signed up for the project. After serious effort, the project met with technical difficulties centering on the need to secure the position of the patient with respect to the device (reported in their master of engineering project report, Home recovery robotic device for hemiparetic stroke patients, by Ian Colahan, Derek Stillwell, and Paula Wang, Cornell University, May 11, 2007).

Even with the difficulty, the project had an upside. A doctor of philosophy (PhD) student, Michael A. Sherback, was not only a great resource to the team, he used his knowledge of oscillators and his keen ability to build a prototype of a novel and usable device that was relatively lightweight and could be portable (**Figure 1**) [1]. We used our college infrastructure and a grant to Volpe and Sherback from Cornell's Clinical Translational Science Center Program to fabricate additional prototypes. We shipped three units to Volpe's Stroke Recovery Group, where they are being used in a research project that is tracking kinematic characteristics of movement in patients recovering from stroke.

Figure 1.
Stroke Rehabilitation System.

SMART WALKER

The Smart Walker project began during a family reunion with my Boston-based cousins. Unfortunately, one of my cousins had developed multiple sclerosis and needed to use a walker. While I had never paid much attention to their use, I was appalled at how poorly his walker assisted him in rolling over gravel in the driveway. In addition, it was difficult for him to lift it up steps to get into the house.

Soon after that, a colleague, Dr. Eli Einbinder, a psychiatrist in New York, New York, called to ask about high-performance motors and batteries and to ask for assistance in fabricating prototypes of his patented concept for an assisted walker. Events seemed to fall into place, and we had a team for fall 2006. Dr. Einbinder was an active contributor to the team, both in time and in funds for parts and services. What I realize in retrospect is that those who joined the team or volunteered seemed to have a personal interest in the project. One of the students had an elderly grandparent who had just begun to use a walker. That student graduated from Cornell University and went to a PhD program in biomedical engineering. Dr. Bruce Land, who helped with the initial microprocessor devices and software, was interested in keeping his father from falling off the curb as he walked.

Dr. Bruce Volpe continued to consult and educate me about infirmity and aging. A gift from John and Michelle Slapp allowed us to begin a team on home healthcare monitoring. Bruce was quick to point out that knowing vital signs alone was not significant if users had no mobility in their homes. With John and Michelle's permission, we expanded the charter of the gift to home healthcare monitoring and mobility, including the Smart Walker.

The Smart Walker project continued into a second year with another engineering team, and we were able to get a team from the Johnson School of Business to develop a business plan for its commercialization. In addition to meeting with Dr. Einbinder, the team met with Dr. Volpe to help guide the marketing and adoption estimates that are so critical in commercial assessment.

In the last year of the project, through the hard work of several students and Dr. Einbinder's generosity, we completed four prototypes (**Figure 2**). Had we been able to build a dozen units, most members of the team would have wanted one of the Smart Walker prototypes, including the inventor.

As one might suspect, student prototypes are not exactly identical, but the key components and software had been reduced to a single simple circuit board. Cost had been identified by the masters of business administration students as critical to the adoption decision. We did not have the time or student expertise to replace the $200 linear motors that activated the brakes with a $5 version that used a simple but elegant mechanical toggle needed for cost and weight reduction. Dr. Einbinder succeeded in getting another patent on his invention and is seeking a commercialization path for the Smart Walker [2–3].

Figure 2.
Smart Walker.

BLINK RESTORATION

The Department of Biomedical Engineering has engaged in research collaborations with several clinical departments at Weill-Cornell Medical College in New York, New York. One of these was the Department of Surgery and related divisions. Mark I. Rosenblatt, MD, PhD, from the Margaret M. Dyson Vision Research Institute, and Gary J. Lelli, Jr., MD, Assistant Professor of Ophthalmology and Oculoplastic Surgery, approached Professor Shuler about a group of patients that could not blink.

These patients suffer from paralysis or tissue scarring on or around the levator muscle and cannot close their eyes fully. If a patient has this condition, the eyes are at high risk for infection and blindness. Current clinical treatments include suturing the patients' eyelids shut or using implanted weights in the upper eyelid, which are less effective during sleep. All existing approaches poorly serve the patients. The doctors inquired about getting engineers to prototype a concept they had. Using technology based on attractive forces (patent in process), they proposed a wearable eyeglass-type device that could automatically blink for patients. Although the semester had already started, students in the college are always looking for new projects.

Peer solicitation is one of the better contact tools I have found at the university for finding team members. In this case, I asked a few current master of engineering students who had also been undergraduate students at Cornell to spread the word on the project opportunity. A graduating senior from the Department of Mechanical and Aerospace Engineering at Cornell joined the project. Using conference calls with the doctors, we established the clinical user requirements and brainstormed an interim device. Using abandoned eyeglasses left in the lost and found, we modified several pairs as prototypes. In addition, the student used three-dimensional computer-aided design software to build mechanical and performance models of the system.

The student met with the doctors in New York City by herself to discuss the prototypes and confirm her understanding of the clinical needs. I feel that direct student-doctor meetings are a critical part of the

learning experience, and I seldom attend these meetings. Students gain this confidence in themselves, clinical needs assessment, and the ability to explain their design rationale. We continued to refine the prototype and engineering models of the design. As one student was graduating, another appeared, looking for a summer project. The newer student learned from the departing student and then took over for the summer to produce functional prototypes for the doctors. That student returned in fall 2010 and began a team project to develop the next version of prototypes and begin work on the automatic blinking concept (she reported on her work to that point in Blink Project, by Nadea Nissanka, Cornell University summer project, 2010).

TEACHING SKILLS TO STUDENTS

In all of these projects, the students initially lacked the skills to fabricate parts, solder wires, match batteries to motor loads, fuse circuits, and use common electrical test equipment, such as volt-ohm meters (VOMs), without destroying them during debugging. I offer a few suggestions to those undertaking these types of projects.

It is important to teach students skills with simple hand tools and how to solder. Few of my students can change the oil in their car (appalling to a engineer of my generation). Teaching students crafting skills is not difficult, but it does take time and patience. One book I recommend is *The American Radio Relay League (ARRL) Handbook for Radio Communications* [4]. It is a compendium of practical data on wires, fuses, etc, and will go a long way to enhancing students' ability to work with real systems. The 20- to 40-year-old versions of the ARRL Handbook have even more material on construction practices. While many of the circuits in the older handbooks used vacuum tubes and high voltage, students should only work low voltage for safety reasons.

Student skills are, in general, excellent with digital electronics and programming but are lacking with analog electronics. When students are using a VOM, expect that they will forget to switch from "ohms" mode to "current" as they take in-circuit measurements—this will kill the VOM. Good VOMs are available in the $10 to $20 range. Buy several. After the third unit is damaged, I ask them, "What might your supervisor at a company think if you damaged a $2,000 instrument?" I usually find that is the last time a VOM is damaged.

I also purchase or supply a variety of example products to compare with the concept under development. Any hardware store or automotive parts company, even Wal-Mart or Sears, will have a variety of electronic parts. Encourage the students to assemble, cut up, patch, and modify them as they wish to develop crude concept prototypes. We did this with a variety of switches for the Smart Walker. A formal design process, engineering analysis, computer-aided manufacturing, and rapid prototyping methods can follow with sufficient time and resources.

Access to colleagues in electrical and mechanical technologies is very valuable. I believe that teaching students to seek out consultants—people with expertise in the area they need—is important. While students may be reluctant to seek the guidance of experts initially, if they understand that most projects require a multidisciplinary approach, they begin to realize that consulting is the preferred path. Teaching students how to request engineering evaluation samples is also a good way to stretch limited project funds.

While this article has focused on projects that were clinically initiated, we routinely accept projects from companies that act as sponsors and team members. Company engineers direct the activities of the teams, and a Cornell faculty member helps with logistics and location of university resources. Students benefit from exposure to both university and company mentors.

Over 200 engineers have graduated from our program since 2005. Our collaboration with external sponsors has become an important part of Cornell's master of engineering program. We believe the program benefits both student and sponsor. Students now embarking on their careers return to recruit students as employees and to sponsor additional projects. We in the Department of Biomedical

Engineering look forward to sustaining these collaborative projects for years to come.

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