Mechanical Engineering Capstone Projects in Rehabilitation Design

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Abstract

We report results of a multi-year project aimed at offering socially relevant capstone design projects (with a rehabilitation engineering focus) to mechanical engineering student teams in their final undergraduate semester. Students meet regularly with one or more experts in rehabilitation over the course of the semester to develop and refine design concepts consistent with a clinical needs assessment. On average, two teams of 3-4 students participate in this project each semester. An overview of several recent design projects is provided, highlighting aspects that particularly leveraged the collaboration and expert involvement integrated into the project team. We also present a novel project element piloted recently, in which an engineering capstone team is paired with a capstone team in advertising at the College of Journalism and Mass Communications (CoJMC). Our anecdotal experience suggests that this approach encourages clear identification of functional requirements and connections to market needs early in the design process, and provides a broader, less siloed capstone experience for engineering students.

Introduction

Engineering undergraduate programs typically include a capstone experience in which students conceive and execute a design, allowing them to demonstrate their cumulative mastery of the design process, analysis, and experimentation achieved during the pursuit of their undergraduate degree. This project also can offer students their first opportunity to interact with a client, practice teamwork, and perform engineering work with high social relevance, all of which contribute to satisfaction of student outcomes targeted by the Accreditation Board for Engineering and Technology. With an aging population, rehabilitation engineering serves as a meaningful focus area for achieving these objectives [1,2,3].

Methods

Students in their senior year participate in a two-semester capstone course series, with the second semester devoted to realizing a design conceived during the first semester. Team size is 3-4 students. By requiring a design pitch (oral proposal) including several design options during the first semester, this allows the majority of the second semester to be focused on refinement and realization of the design.

A subset of the design project topics are centered on rehabilitation engineering, with design problems pitched to students by the faculty. An initial meeting with clinicians at [name of institution removed for review] by the beginning of the second semester provides an orientation to the client requirements. Several additional design reviews are held throughout the semester to keep the design process aligned with the requirements. Sample projects are described as follows.

Project 1: Fall-prevention walker
Walkers are often used to improve stability and promote mobility. However, most walkers have certain usability limitations. Walkers without wheels need to be lifted at each step, and walkers

with wheels require brakes to avoid sliding out from under the user during a fall event. Hand brakes are not very useful because many users lack the hand strength to effectively use them. A first team of students designed a wheeled walker that included a wheel lock triggered by loading the walker vertically, with actuation of the lock being tunable to the weight and preferences of the user. A second team designed a load-triggered outrigger mechanism to widen the footprint of the walker and prevent tipping during a fall event.

Project 2: Sit-to-stand device
A survey of available sit-to-stand rehabilitation devices revealed that the motions generated are not very correct biomechanically, in terms of maintaining the center of mass above the center of pressure (the feet) throughout the motion. A student team designed a motorized rehabilitation device which uses cables attached to a torso harness to more closely mimic standing biomechanics by pulling the trunk forward and then upward in a two-step motion.

Project 3: High-reach device for wheelchair (with COJMC)
Individuals confined to wheelchairs may encounter difficulty trying to reach items on high shelves, on the far edge of a counter, etc. Two student teams independently designed mechanical high-reach devices to serve as wheelchair accessories. Constraints on weight and size, imposed to accommodate the needs of a typical wheelchair user, made this a challenging design problem.

The second of these two engineering teams participated in a pilot effort in which a capstone team from the College of Journalism and Mass Communications was pitched the same project topic. This team's focus was on the informational campaign to communicate the value of the product to potential stakeholders (end users, hospitals, and others), including print and digital media. The two teams met early in the process with the client to clarify design goals and the resulting value proposition.

Results

The formalization of the first meeting with clinicians helps students more quickly and clearly define their design problem and the associated constraints. Furthermore, this problem definition phase was enhanced by the advertising pairing, as the information shared between the engineering and advertising teams helped the engineering students to ask good questions; the advertising students also performed stakeholder research which provided refinement of the design objectives. This cross-pollination helps to satisfy ABET (Accreditation Board for Engineering and Technology) accreditation student outcomes criterion (h) related to developing an understanding of the impact of engineering solutions in a global, economic, environmental, and societal context, as well as criterion (d) related to functioning on multidisciplinary teams. The end result was that these teams were able to produce at least a partial prototype of their designs; many other teams only produce computer models to accompany their design reports.

Since students self-select for these projects, it is impossible to obtain meaningful data on student attitudes toward the subject matter of rehabilitation engineering in comparison to their peers. Nevertheless, it is clear that exposure to this type of design problem provides a backdrop for students to work in a more multidisciplinary way and see the direct societal relevance of their work. It also prepares them to some extent for future experiences in graduate programs or in

industry; for a few of the design teams, products of their work have included published articles and/or technology disclosures.

Conclusions

Fifteen teams over four years have performed capstone design projects focused on rehabilitation engineering. These projects have provided a broader perspective for students to appreciate the societal relevance of the engineering profession. Presentations, publications, and technology disclosures resulting from the students' work have served to disseminate this information and bring these positive aspects more into the public view. Collaboration with advertising students provides mutual benefits, particularly improved understanding of stakeholder requirements for the engineering students and the realism of working with a product development team for the advertising students. Achievement of certain student outcomes targeted in engineering accreditation criteria is an added benefit.

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