2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34591

WIP: Adaptive Design Engineering to Enable People With Disabilities in the University Setting

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Introduction. Mobility-based disabilities, whether prolonged or temporary, present functional barriers to individual independence and success. Those with diseases such as cerebral palsy and muscular dystrophy in addition to individuals with spinal cord injuries often require aid from a caregiver, specialized tools and equipment, or both to carry out activities of daily living (ADL). Of the nearly 20% of people living with a disability in the United States, approximately 6 million use assistive technology to overcome ADL challenges [1-3]. Previous work performed by the Warren group and others have focused on incorporating design of assistive tools and technology to assist children and others with ADL, in addition to using such tools for improving participation of people with disabilities in the classroom [4-6].

Over 19% of undergraduates and over 11% of doctoral students (enrolled) were reported to have some type of disability between 2015-2016 [7]. These individuals are significantly underrepresented in the STEAM arenas. In fact, only 1% of graduate students with mobility-based disabilities received a PhD in 2017 [8]. University level students are uniquely impacted by disabilities as campus activities require additional considerations in regard to accessibility including accessing disperse classrooms with a wide range of seating arrangements, accessibility aids, and doorways. While classrooms may have designated wheelchair areas, the provided work surfaces are frequently limited or non-existent. This leads students to spend significant effort finding techniques to write notes or complete exams prior to focusing on the course work itself.

As a result of the design thinking approach we have introduced into our engineering curriculum [9], it is evident that team-based activities and prototyping geared toward solving these problems can result in increased inclusion of students with disabilities. These solutions can have a dramatic impact on the ability of people with disabilities to complete coursework and engage in course-based ADL independently. Incorporation of guest lecturers including therapists, rehabilitation engineers, and people using assistive technology (known as “need-knowers” during the course) in conjunction with design thinking and rapid prototype fabrication led to removal of two barriers to success identified by students with disabilities. The purpose of this paper is to discuss results from two semesters of a new elective engineering adaptive design course geared toward inclusion of people with disabilities in STEAM and participation of relevant members of the community, medical professionals, and entrepreneurs in a “hackathon” style environment.

Methods. During each offering of our “Adaptive Design for the Community” course to date, 24 students in multiple degree programs at both the undergraduate and graduate level formed design teams focused on a problem or challenge faced by students or other members of the local community with disabilities. These teams were 4-5 students in size. Need-knowers were first interviewed by the entire team in order for them to obtain an understanding of the problem. The interviewees were then consulted at various stages of the design process including testing prototypes. Several prototyping milestones were completed throughout each semester with the final deliverable being a team produced video presenting each team’s solution to the problem. Online and in-person learning activities were simultaneously applied throughout the semester including the IDEO design thinking approach in order for each team to develop and practice design-oriented skills [10]. In addition to the team projects and coursework, students were able to participate in a university design challenge that promoted adaptive needs and inclusion of people with disabilities in engineering. Each team developed a challenge or activity in which participants attempted to complete a daily living activity with an applied constraint simulating a specific disability. Both able bodied individuals and those with disabilities participated in the event.

Results. One of the adaptive design teams selected a project to develop a typing/writing utility device for wheelchair users. These need-knowers often face specific challenges with the height and positioning of fixed desks within the university environment. Standard classroom desks and tables interfere with both the ability to type and maneuverability for fitting wheelchairs (especially larger motorized designs). For individuals who use a wheelchair, the horizontal surface on the provided desks and tables may not be ergonomically sound for positioning hands and wrists. Typing comfort and speed are critical needs as course curriculum becomes more technology dependent. After 8 weeks of the first semester of the course, the team that selected this project constructed a working prototype that could be fitted to a wheelchair in a fashion that avoided interfering with its normal function. User testing was carried out in the classroom to determine user experience and measure typing speed with and without the prototype. The need-knower was able to type at a speed of 5 words per minute without the prototype attached. However, with the prototype installed the individual reached a speed of 30 words per minute. Not only did the device assist the user with coursework, but it allowed the student to complete his doctorate degree the following summer.

A second design team selected a project focused on building entry of wheelchair users through modification of "push-buttons" previously fitted doorways. This team determined through need-knower interviews that standard installation of these devices frequently causes unnecessary barriers and can even cause damage or injury if the wheelchair is positioned against the automatic door. This team's final solution to the problem was entirely different from the others as it did not result in a physical prototype. Upon experimenting with levers and extended reach devices, the team discovered the doors were already fitted with specific radio frequency antennae that could be activated by a handheld remote. This illustrates the important skill of pivoting during design engineering. With permission from the Dean of the School of Engineering, the team activated the sensor and programmed the remote for wheelchair users to test. This project soon launched an effort to explore other buildings across campus and may soon result in handheld remotes being used at other public facilities and venues.

In consideration of the two sample design projects discussed above and others in "Adaptive Design for the Community", we determined that team-based design with direct inclusion of individuals with disabilities in the prototyping process can result in rapid, measurable removal of barriers to success. The writing/typing device and the door opening approach are representative of second order changes that assist students with disabilities in moving beyond single building or classroom challenges. Instead of requiring development of new solutions to enable computer-based notetaking electronically each time students attend a course in a different building, the design team's solution will allow these individuals to succeed in any academic environment whether in a crowded library or university coffee shop. Typing speed can also be maintained with such an approach. Similarly, any automatic door opening framework fitted with a radio frequency antenna can be activated and programmed to open with a handheld remote as opposed to opening into someone's wheelchair or leg.

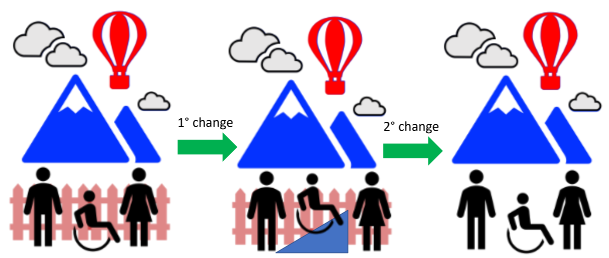

Figure 1. Illustration of how students with adaptive needs face many challenges to pursuing opportunities that equal their counterparts (at left). A first order change, such as the installation of ramps and other assistive devices, gives equal access to wheelchair users (middle). A second order change will remove those obstacles altogether (right).

The approach of our course to team-based engineering design solutions for people with disabilities can best be summed up by Figure 1. This illustration shows how wheelchair users face challenges that are not perceived by able-bodied colleagues. The majority of solutions for the needs of people with disabilities are most often first degree or first order. These include installing a ramp alongside stairs (see Figure 1, middle) or push-button mechanisms in difficult to access locations. Such interventions give the wheelchair user perspective and access equal to their colleagues, but they are limited to the site at which the intervention takes place including specific buildings or even classrooms. Prototypes and other solutions (including opening doors fitted with automatic opening levers) presented by the teams enrolled in our adaptive design course represent second order changes (see Figure 1, right), which remove the barriers entirely.

Conclusions. By creating a device that is bespoke to the user such as the wheelchair typing apparatus, wheelchair users in any university setting will be able to use any workspace on campus. In future iterations of our adaptive design coursework, we will explore similar projects for other disabilities and further evaluate the potential of real-world ADL challenges informed by experts in the field who either experience disability-related challenges firsthand or have direct experience with these individuals. We feel strongly that both design and development of second order tools along with awareness resulting from interaction with specialists and need-knowers will lead to future improvements and inclusion of members of the adaptive community in university coursework and research settings.

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