Capstone Design CONFERENCE 2024
JUNE 3–5, 2024 ▶ KNOXVILLE, TENNESSEE

Multidisciplinary, human-centered design projects attract a diverse cohort of engineering students

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Lack of diverse representation in engineering professions can lead to suboptimal engineering solutions and gender-biased design. Despite national efforts to recruit female students to engineering programs women remain underrepresented and post-graduation leave the profession at higher rates than their male counterparts. Universities can recruit and retain women engineers by adapting curriculum and providing support systems to promote the success of a diverse student body as they enter the workforce. University of Detroit Mercy has recently leveraged a human-centered capstone program along with funds from a Clare Boothe Luce grant to expand a curriculum known to attract women to the mechanical engineering department. This paper outlines Detroit Mercy's expansion of the capstone program and evidence of resulting opportunities for women in leadership, implementation of a multidisciplinary minor in biomedical design and increased participation of undergraduate and graduate students in research.

Keywords: Multidisciplinary, human-centered design, gender equity

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Transforming a Male-Dominated Profession

Prospective students traditionally are attracted to professions in which they feel represented. Additionally, the male-dominated engineering profession can appear to female students as less human-centric than other professions such as nursing or teaching. As a result, even after a multi-decade effort to recruit young women, females remain under-represented in engineering programs and post-graduation are more likely to leave the workforce for non-engineering careers than male counterparts[1].

A critical consequence of lack of gender diversity in engineering undergraduate programs is that male-dominance continues to proliferate the profession, ultimately resulting in sub-optimal engineering solutions and gender-biased design[2, 3].

To increase participation of women in engineering design, undergraduate engineering programs need to adapt by providing models of opportunities for females. This can be accomplished through intentional efforts to increase women role models and internal support systems while developing curricula with clear, human-centric pathways attractive to prospective female engineering students.

Making a Difference: Clare Boothe Luce and an Innovative Capstone Program are Challenging the Status Quo

Detroit Mercy in recent years has actively aimed to recruit female engineers by recruiting and increasing the visibility of female leaders/role models while expanding a curriculum attractive to women. Efforts have leveraged an existing mechanical engineering capstone program focused on providing assistive devices to people with disabilities as an avenue for recruiting women to engineering.

Clare Boothe Luce Professorship

Upon recognition of the popularity of capstone assistive technology projects among female students, Detroit Mercy's mechanical engineering department applied for a Clare Boothe Luce (CBL) Professorship (*https://www.hluce.org/programs/clare-boothe-luce-program*) to expand the innovative capstone program through the addition of new faculty with biomedical engineering expertise. Through its Clare Boothe Luce Program, the Luce Foundation is the leading private source of funding in higher education for women in STEM. In 2017, Detroit Mercy's CBL award provided funding over a 5-year period to hire a female faculty member focused on (1) leading human-centered capstone projects, (2) establishing a program in biomedical research, and (3) increasing female mentorship in engineering.

Innovative Capstone Projects

The existing mechanical engineering capstone program was known to attract women. The program emphasizes human-centric design by requiring students to design and build assistive devices capable of addressing unmet needs for people with disabilities[4, 5]. The

multidisciplinary nature of the projects allow nurses, engineers, and biology students to collaborate on a common solution.

CBL Launched Opportunities for Female Faculty and Capstone Students

Dedicated Faculty with Biomedical Expertise

The CBL sponsorship provided a female faculty member with expertise in biomedical engineering dedicated to expanding the existing capstone program while expanding opportunities for biomedical, human-centered research and design.

CBL funds were pooled with alumni donations to build a 600 sq ft Assistive Technologies (AT) Lab dedicated to the design and testing of medical devices and human performance. The AT Lab is equipped with a motion capture system, electromyography, pressure sensors, temperature mats, a balance board, various goniometers, anthropometers, dynamometers, and other force gauges to accurately quantify and assess human capabilities and human performance. The lab houses a 3D printer and sits next to the machine shop for convenient access to real-time prototyping capabilities. The lab is available to capstone teams throughout the capstone experience for both development and testing of capstone projects.

Expanding curriculum

Further expanding student's academic opportunities, a Biomedical Design Minor was established allowing students from all engineering, science and health professions the opportunity to hone skills in a cross-disciplinary manner to solve human needs through design. Two new courses, ENGR 1400: Intro to Biomedical Engineering and MENG 4400: Occupational Biomechanics, prepare students with the biomedical skills necessary to design for humans further enhancing the assistive technology senior projects. It is of note, that as of the Fall 2023 semester, 87% of the students enrolled in the biomedical design minor were female.

Opportunities for Student Leadership

Matching university funds provided scholarships for graduate student teaching assistants in the mechanical engineering capstone course and to support undergraduate and graduate research assistants. Throughout the 5 year grant period two female teaching assistants were recruited to support the capstone program. Each student had completed the capstone program as an undergraduate and expressed interest in biomedical research.

Opportunities for Undergraduates and Graduate Research

Beyond providing diverse representation of teaching assistants in the capstone program the students also benefitted from scholarships and stipends allowing them to complete graduate degrees. Of the capstone teaching assistants, one simultaneously completed her PhD in Mechanical Engineering while the other earned her Masters in Mechanical Engineering (MME). Upon exposure to biomedical research projects through capstone several other students sought research experiences through the AT lab at the undergraduate, masters or PhD level.

Human-Centric Projects Support Mission Driven Learning

Detroit Mercy's assistive technology projects align with the University mission through service learning. Projects are unique compared to other university's capstone experience in two ways:

- Project focus on a human client, not a pre-defined problem
- Engineers work with student nurses to develop collaborative solutions

Rather than assigned a pre-defined problem, each design team is introduced to a client with a disability. The students visit the client in the first weeks of the fall semester to learn about the client, his or her condition, and how the team could assist by building a device to meet client needs.

From there the course moves at a rapid pace. In Prototype I (fall semester) the students work to define a problem statement, define requirements/specifications, use idea generation techniques to generate 100 possible solutions, narrow the solutions, and create a design proposal and presentation with a mock-up prototype.

In Prototype II the teams refine their design through a series of design reviews and assessments and ultimately build and test the device. In addition to a final design report and presentation the team provides a working prototype for the client to take home. Examples of recent projects include:

- An accessible easel allowing a 62-yr old client with a spinal cord injury to continue to paint from his wheelchair.
- An adjustable wheelchair workstation tray for a quadriplegic client with capability to position/tilt using a custom rod and electronics controlled by the chin.
- A portable/removable dressing device attached to a wheelchair arm rest to assist a client in donning pants.

Building Relationships Fosters Success

While the projects do serve a client, the true value of the program lies outside of engineering in the relationships developed between disciplines and with clients.

First, student nurses and engineers learn to communicate their individual skills with one another in a manner that strengthens the overall project. Early in the project the student nurses initiate contact and facilitate conversations with the clients. They help bridge the gap of medical knowledge and explain medical conditions to the engineers. All students actively participate in the creative design process. By the end of the semester, engineers are comfortable with client interactions and medical terminology while many nurses participate in building devices in the machine shop. All students provide valuable input from various perspectives to ensure product safety in the final design stages and by the end of the capstone experience recognize the collaborations lead to superior design. One student nurse remarked,

> *"I never would've thought to put these two curriculums together… We all have different mindsets and experiences, when the engineers are thinking of building something they're thinking of keeping it together so it doesn't break and I'm thinking of safety concerns. We moved away from certain designs because I had the insight to say 'well this type of model could create pressure ulcers or increase the risk of skin damage."*

Another value of the program lies in the relationships built between students and clients. The ability to work with a client who has a different background and abilities than most of the students enables them to consider how inclusive design benefits a much wider range of people. A year after participating, a former client reached out to the program stating,

> *"I wanted to give you an update on how much I love the easel that your students made for me. Lately I've been pumping out the paintings. Please let your students know they helped me out so much."*

Although many Detroit Mercy students will go on to work outside of the medical device industry, they will always take with them the ability to identify how users with a range of abilities will interact with a product making them better design engineers or nurses with a better understanding of medical equipment design. However, the true spirit of the University mission is in the friendships established as evidenced by students continuing to communicate and visit clients post-graduation.

Summary of Program Success

The Clare Boothe Luce professorship doubled the number of female faculty in the mechanical engineering. The additional professor expanded the support structure for women engineers by acting as a co-advisor to the Society for Women Engineers student chapter, initiating a yearly women-in-science book discussion, and hosting panel discussions to link current students with engineering alumni.

Capstone team diversity with respect to both gender and multidisciplinary teams has led to successful team projects. Despite COVID challenging in person interactions between teams and clients, since August 2021 8 of 9 capstone projects were successfully completed and safely delivered to clients. Additionally, corresponding expansion of academic and research opportunities proved attractive to female students. Between 2017-2023, 76% of the research students working in the assistive technology lab and 87% of students pursuing the biomedical design minor identify as female.

While CBL funding ended in 2023, the assistive technology program and design projects continue. The University continues to employ the professor who has successfully obtained funding for the assistive technologies lab through both grants and alumni donations. Design projects receive funding for materials and supplies through local industry sponsors.

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