Final Technical/Scientific Report (FTR)

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Executive Summary

BETTER Capstone supported 29 student project teams consisting of 155 students over two years in developing transformative building energy efficiency technologies through a capstone design experience. Capstone is the culmination of an undergraduate student's engineering education. Interdisciplinary teams of students spent a semester designing and prototyping a technological solution to a building energy efficiency problem. During this experience students utilized the full design process, including the manufacturing and testing of a prototype solution, as well as publically demonstrating the solution at the Capstone Design Expo. As part of this project, students explored modern manufacturing techniques and gained hands-on experience with these techniques to produce their prototype technologies. This research added to the understanding of the challenges within building technology education and engagement with industry. One goal of the project was to help break the chicken-and-egg problem with getting students to engage more deeply with the building technology industry. It was learned however that this industry is less interested in trying innovative new concept but rather interested in hiring graduates for existing conventional building efforts. While none of the projects yielded commercial success, much individual student growth and learning was accomplished, which is a long-term benefit to the public at large.

Project Highlights

The goal of the Building Efficiency Technologies by Tomorrow's Engineers and Researchers (BETTER) Capstone project was to support twenty student project teams in developing transformative building energy efficiency technologies through a capstone design experience Interdisciplinary teams spent a semester designing and prototyping a technological solution to a posed building energy efficiency problem. During this experience students utilized the full design process, including the manufacturing and testing of a prototype solution, as well as publically demonstrating the solution at the Capstone Design Expo. As part of this project, students explored modern manufacturing techniques and gain hands-on experience with these techniques to produce their prototype technologies. Also as part of this project, many student teams were individually partnered with company sponsors. This type of a partnership is not possible without the BUILD program's support, because there is a need to disrupt a chicken-and-egg problem to engage both large and small building efficiency companies to participate in the capstone experience.

After the first semester piloting the project, it was clear that there was a high demand from the students and more project teams were possible than initially proposed. In the proposal, the target was to support ~20 project (~100 students). By the conclusion of the project, we had performed 29 projects engaging 155 students (~50% increase in size beyond proposed). However, even with student interest, we struggled to find enough industry mentors. We primarily tried working with local industry mentors but we did have mentors in Boston, MA and Oak Ridge, TN. Overall we noticed a shortage of industry interest in building science and building energy efficiency wanting to partner with universities.

	Semester 1	Semester 2	Semester 3	Semester 4
# of projects	5	8	7	9
# of students	25	44	36	50

The goal for each semester was 5 teams consisting of 25 students. We exceeded this target after realizing that we could support more students after the first semester.

From this effort, one project team went on to form a start-up looking at building integrated PV installation. Follow-on funding of $20k was received as part of a Start-Up Summer program at Georgia Tech for the team to learn about commercialization and gather customer feedback during the summer between the second and third semester of these four semesters long BETTER Capstone project. Unfortunately, this start-up project was not continued passed that summer experience. This effort also worked with two notable start-up companies (Embr Labs and Emrgy Hydro) who have since integrated parts of the student projects into their technology and development. We also note that one of the students got a job with their industry mentor as an outcome of this effort. While several students filed invention disclosures and explored obtaining preliminary patents, to our knowledge, none of the students pursued patents due to expense of the process.

Learning Opportunities

One primary take away is that there were different interests from different industry mentors. Large companies saw this as an opportunity for university relations and were interested in hiring students (*e.g.*, workforce development). Smaller companies (*e.g.*, start-ups) were interested in working with students to develop technology that could be adopted. To achieve impact relevant to BTO, it is more ideal to work with small companies (*e.g.*, start-ups) because they are nimbler and willing to try and commercialize student ideas/solutions.

Partners with Industry & Academia

We had initially proposed working with nine industry partners. Of those initial nine listed in the proposal, four of the industry partners backed-out for various reasons (*e.g.*, timing was not right or there was not sufficient bandwidth to work with students). However, we were able to find additional industry mentors once the project was underway and in total we had 10 industry mentors plus 5 internal mentors present building energy efficiency projects to students.

One way to improve industry partnerships would have been to work more closely with BTO portfolio partners. Only one BTO project with ORNL (mentor Dr. Roderick Jackson) was undertaken. If BETTER Capstone is undertaken in the future, assistance from BTO program management in partnering with BTO portfolio members would improve the process and likely the outcomes.

Industry Mentors	Internal Mentors
1. Embr Labs	1. Prof. Todd Sulchek
2. Emrgy Hydro	2. Prof. Shannon Yee
3. United Technology Corporation	3. Prof. Thom Orlando
4. Sawhorse	4. Prof. Albert Frazier
5. Oak Ridge National Laboratory	5. Dr. Kereshmeh Afsari
6. Advantage Renewable Energy LLC	
7. Fox Theatre (historic theatre)	
8. Emerson	
9. Perkin+Will (architecture firm)	
10. Green Wave Innovation	

Products

The primary product developed by this work are individual project reports. The individual project descriptions and student bios for each project can be found with Deliverables 1.0 for semester 1, Deliverable 3.0 for semester 2, Deliverable 5.0 for semester 3, and Deliverable 8.0 for semester 4. The final reports of each project can be found in Deliverable 2.0 for semester 1, Deliverable 4.0 for semester 2, Deliverable 6.0 for semester 4, and Deliverable 9.0 for semester 4. They are not reproduced herein for brevity. These project reports contain descriptions and objectives for each project.

Additionally, a discussion of this combined research and educational activity was briefly discussed and published in an engineering education conference proceeding:

Telenko C, Jariwala A, Saldana C, Sulcheck T, Yee SK, Newstetter W, Kurfess T (2016). Examples of Synergies between Research and Hands-on Design Based Learning. *ASEE 123rd Annual Conference & Exposition* (15472)