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Work in Progress: Prosthetic Design Cases as an Educational Tool In and Out of the Classroom

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Abstract

This study examines student educational outcomes from working on prosthetic limb design inside and outside of the classroom. The Helping Hand Project (HHP) is a nonprofit organization that builds custom prosthetic devices for children with amputations. The HHP does so through the involvement of students working in an extracurricular club, and by partnering with the Design and Manufacturing II course, a class open to 3rd year engineering undergraduates in the UNC & NCSU Joint Department of Biomedical Engineering. In this study, student outcomes, which include technical skills, design ability, teamwork, and business skills, were surveyed before and after building prosthetic devices either in or out of the classroom. This will aid in identifying where students perceive the value in such an activity and allow comparisons between in and out of classroom settings. Survey results from students in the design class on average improve in each category, whereas students in the extracurricular club activities saw improvement only in the technical and design skills categories. In each category, the design students saw on average a greater increase in confidence.

Introduction

The benefits of using design cases in the classroom has been well established. These benefits include increased student engagement and greater retentiveness of material to increase learning outcomes for students. This is why both ABET and the BME community place a strong emphasis on design as part of the undergraduate curriculum [1]. We are conducting a study to determine if learning outcomes are also improved through student involvement in similar design activities that are part of an extracurricular club.

The Helping Hand Project (HHP) is a nonprofit organization that serves those with upper- limb differences through the creation of prosthetic devices. The prosthetic abandonment rate is significantly higher in cases where the user is not provided with a device at an early age [2]. The HHP designs custom upper-limb prosthetic devices intended for use by people with limb differences under 18 years of age, with the intent of preparing them to use a professionally made prosthetic device when fully grown. Many of the volunteers are university students, who use the resources available to them at their university to design the devices. The HHP has engineering students work on designing devices both inside and outside of the classroom. There are on average 50 involved members each semester.

In the classroom setting, this is accomplished as part of a BME Design and Manufacturing II class. This is a semester long required course that teaches 3rd year engineering students the basic tools and procedures of modern design practice as well as traditional and modern rapid manufacturing technologies/techniques. On average 40 students complete the course each semester. Students in the class are given a design project to work on over the semester, which is used to facilitate a deeper understanding of the course skills. In the fall of 2017, students in this class worked on a case provided by The Helping Hand Project. The HHP also offers students the opportunity to be involved in device design independent of a design class through an extracurricular club. Students in this club form teams and are provided with a case to work on for the semester. These teams don’t receive course credit for their work and lack formal deadlines, however they have fewer restrictions on device design requirements.

Both of these settings offer enriching educational opportunities for the engineering student, and the goal of this study is to evaluate student outcomes as a result of their involvement. In this study, students are asked to rate their own ability in a number of different areas commonly used to evaluate engineering education quality, including technical ability, understanding of the design process, teamwork, and organizational skills. Each broader area has questions that look at discrete abilities. This study also compares student outcomes from participation in The HHP as an extracurricular activity to student outcomes from participation in the design class.

Methods

The duration of this study was one semester, which was 16 weeks in length. Students were surveyed both before the semester began and after its completion. Students fell into two categories: those who worked on prosthetic hands within the Design and Manufacturing II class, and those who worked in teams outside of class directly with The Helping Hand Project.

Students in the class met for 3.5 hours each week as a class, where they were taught design principles central to the engineering process - this included technical skills, design process fundamentals, teamwork, and leadership skills. This class was taught by a full-time instructor, who split class time into lectures on the above skills and to meet with individual student teams to discuss progress. In their designs and prototypes, students were required to build all components using 3D CAD software, to utilize electromechanical actuation, to 3D print most components of their device, and to use laser cutting for at least one device component. Students were required to present a functional prototype at the end of the semester, in addition to monthly design reviews where teams would present their work thus far. Students generally worked in groups of 5.

All the students working with HHP as an extracurricular activity met for half an hour each week, where they would share project updates with other student design teams. The HHP provided four student design consultants who would meet with the student teams during this time to discuss progress and offer suggestions. There were no requirements on usage of different manufacturing processes. Students were expected to present a final prototype at the end of the semester, however there were no set deadlines during the process teams would have to meet. Student group size varied - some worked independently or in pairs, others in groups of 5.

Students were asked to self-evaluate their competence in areas identified earlier using a Likert scale [3], where 5 represents the highest degree of proficiency, and 1 the lowest. Each area was broken down into subcategories to better evaluate specific outcomes. For example, technical skills included: 3D Computer-Aided Design(CAD), object-oriented programming, electronics design, 3D printing, and laser cutting.

The change in each student’s response between their pre-semester and post-semester surveys for each skill was calculated. This gives an indication of how each student perceives their ability to have changed over the course of the semester. The average self-scored value for each skill is reported separately for the design class and extracurricular club. The average change in self-scored value is also reported separately for the design class and extracurricular club. The survey was designed so that a positive increase in score represented a perceived increase in ability. This gives an indication of how each student thought their ability changed over the course of the semester in relation to the project.

Results

Table 1 provides a summary of the survey results.

Categories	**Class - Start**	**Class - Finish**	**Class - Change**	**Club - Start**	**Club - Finish**	**Club - Change**
Technical Skills Section						
Comfortability with CAD	3.33±0.94	4.67±0.69	1.33±0.75	2.85±0.57	3.14±0.64	0.29±0.70
Comfortability with Programming	2.83±1.07	3.50±1.12	0.67±0.94	2.43±1.22	3.00±1.07	0.57±0.73
Electronics Design Skills	2.67±0.75	4.00±1.34	1.33±1.25	2.28±0.90	2.71±1.16	0.43±0.73
Ability to use 3D Printing as a Manufacturing Method	3.00±1.00	5.00±0.76	2.00±0.69	2.85±1.21	3.14±1.46	0.29±0.45
Ability to use Laser Cutting as a Manufacturing Method	3.50±0.96	4.13±1.11	0.67±1.11	2.00±1.28	2.29±0.88	0.29±0.70
Design Skills Section						
Mastery of the Design Process	2.83±0.69	4.67±0.58	1.83±0.37	3.00±1.08	3.57±0.49	0.57±1.18
Comfortability in Designing Devices for Human Use	3.00±1.29	4.50±0.58	1.50±1.12	2.71±1.03	3.57±0.90	0.86±0.99
Ability to handle Unforeseen Challenges	3.33±1.11	4.50±0.47	1.17±1.34	3.71±0.57	4.14±0.83	0.43±0.73
Comfortability with Documenting the Design Process	3.00±1.00	4.33±0.94	1.33±1.11	3.43±0.76	3.86±1.12	0.43±0.73
Team Skills Section						
Team Communication Skills	3.50±0.76	4.67±0.69	1.17±1.21	4.45±0.47	4.29±0.45	-0.14±0.35
Conflict Management Ability	3.67±0.94	4.17±0.75	0.50±0.50	5.00±0.48	4.43±0.73	-0.57±0.64
Leadership Ability	2.67±0.75	4.33±0.50	1.67±0.69	4.29±0.63	4.00±0.76	-0.29±0.49
Business Skills Section						
Budget Management Skills	3.83±0.90	4.33±0.75	0.50±0.50	3.58±0.96	3.29±0.70	-0.29±1.03
Timeline Management Skills	3.83±0.69	4.17±0.75	0.33±0.47	4.14±0.93	3.71±0.70	-0.43±0.90

Table 1. This shows the average change of perceived skill for each question asked, where mean is reported first, then standard deviation after the comma. Sample size of design course students is 6, sample size of independent students is 7. A Likert scale was used, where a 5 represents the highest degree of proficiency, and 1 the lowest.

With regards to technical abilities in *Table 1*, students in both the course and the extracurricular club saw students start at similar levels of comfortability with CAD, Object-Oriented Programming, Electronics Design Skills, and ability to use 3D printing as a manufacturing method. However students in the design class were a lot more confident initially in their ability to use laser cutting than the club. While both the class and club saw increases in each of these abilities by the end of the semester, the most significant improvements were for the design class students with regards to CAD comfortability, electronics design, and ability to use 3D printing as a manufacturing method.

Students in the club and class had similar levels of comfortability with the design process at the start of the semester, and while both groups saw an increase on average in their comfortability with the process, again the design class students saw greater increases in student evaluations. Both groups had relatively high standard deviations for each design skill relative to questions within other categories.

Within team skills, the design students had much lower scores at the beginning of the semester than the extracurricular club, however saw an average increase in all subcategories, most notably team communication and leadership ability. However the extracurricular club saw a decrease in each of these categories. Standard deviation remains relatively low for the change in perceived ability each category saw between the start and end of the semester.

The students in the design class and club had similar self-reported scores for business skills. By the end of the semester, students in the design class increased on average, while club students decreased on average. However the changes in this category were smaller in size than those of prior sections. The class though had low deviations in this category, while the club saw much higher deviations.

Discussion

The design class's main focus is to educate students on the design process and improve their technical abilities. In this regard, the class is successful at teaching what it's supposed to, most notably in 3D CAD, electronics, and 3D printing under technical skills, and mastery of the design process, designing devices for human use, ability to handle unforeseen challenges, and comfortability with documentation under design skills. However it should be noted that another factor to the large increase in electronics aptitude is an electronics course many of the students took over the same semester. The class was also modestly successful in teaching team and business skills, most notably team communication and leadership ability within teamwork category. This can be taken to mean that students perceive the class as having a positive outcome on their ability as engineers with regards to technical ability, using the design process, teamwork, and business skills.

The extracurricular club saw increases in the technical skills and design process sections as well, however less change when compared to the class outcomes. The class even saw a modest decrease in student self-scores in teamwork and business skills. One possible explanation for the differences between the class and club outcomes is that lack of a rigorous process for students in the extracurricular club. Design class students had monthly review periods, and were required to sit down with the course instructor weekly, while the club didn't impose any requirements except for the final review at the semester end. Another is the class emphasized group work heavily as there was an expectation all students within the standard group of five to contribute, whereas the teams within the club saw workload spread out unevenly within groups. Students within the class met weekly with a PhD faculty member, while club students met with HHP-appointed design consultants, who were other undergraduate students. There's also the important factor that students are generally fairly motivated by grades, whereas the club had no such incentive. Overall though, the extracurricular club saw most scores increase, indicating that it is having a positive effect on students.

One of the limitations of this study has is that students self-scored their abilities. This means the results are subject to individual perception, which is an interesting measure however leaves a desire for a more objective measurement. Another limitation is the small sample size, which in part contributed to the larger standard deviations. This makes it harder to determine the significance of outcomes between both groups. The language used in the survey was internally developed and based on evaluation metrics used by the BME senior design capstone course. A limitation is that club students who haven't taken engineering courses may be unfamiliar with the terminology and have difficulty self-scoring. To provide a more comprehensive measurement, in the spring of 2018 an independent design instructor will be evaluating student ability in these categories. The instructor teaches the senior capstone class, a yearlong course for 4th year Biomedical Engineering students where students identify a need in the clinic, design, and develop a device to target that need. The instructor will use their final design and prototype and knowledge of the students' technical and leadership ability to score students in each of these categories. This will provide a measure independent of self-evaluation and allow quantification from an objective perspective on how the extracurricular club affects student educational outcomes. This will also serve to address one of the weaknesses of this study that was the small sample size that resulted from asking students to participate instead of making it compulsory.

References/Bibliography

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