The Impacts of a Human-Centered Design Project on First Year Engineering Student Perceptions of Success

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Background and Motivation

In our rapidly changing world, even more is demanded of engineering graduates than what was previously expected [1, 2, 3]. Research has pointed to a disconnect in the skills that employers desire of engineering graduates and the skills that university coursework actually emphasize. Employers have been pushing for colleges and institutions to move beyond just "hard engineering" and prepare their students with a myriad of non-technical skills to best succeed in the 21st century workplace. Surveys of industry employers suggests a greater emphasis on attributes including flexibility, conscientiousness, integrity, problem solving, communication, and organizational skills [1]. ABET reflects these demands, outlining the desired skill-set of engineering graduates to include:

- an ability to apply knowledge of mathematics, science, and engineering
- an ability to communicate effectively with a range of audiences
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- an ability to function on multidisciplinary teams and
- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics[4].

Universities have thus been more carefully examining the design of their engineering curricula, and especially the design of introductory courses. Previous research has shown that project-based assignments presented in these first year courses can help expose students to a range of technical and non-technical skills, while also piquing student interest early on in their career [5]. Such projects may focus around a real problem from the surrounding community [6, 7, 8] or a particular client [9]. Research has yielded largely positive results on student growth in the less technical areas of engineering through the implementation of such client-based and/or real world design projects [6, 8, 9].

Some of these first-year engineering studies, such as Atman et al's and Swenson et al's, have examined the attributes of novice engineers as they take up a design challenge, and how their processes differs from those of more experienced engineers [2, 10, 11]. Much of this earlier research leverages classroom video footage and student created artifacts to formulate differences across novice and experienced engineers. However, there remains space to better understand the evolution of novice engineer's thought processes and perceptions as they become a more experienced engineering student within the progression of a class. This paper hopes to contribute to the literature in exploring, *how do first-year engineering students' reflections around success in engineering change after a client-based project?* Leveraging student reflections from both the beginning and end of the course, this paper examines a professor's implementation of a final, client-based project and explores how his students' understandings of success start to reflect more of the complex skill-set for which the engineering discipline calls.

Research Context

The following data was collected in a first-year introductory engineering course on robotics at Tufts University, a private university in Medford, Massachusetts with approximately 600 engineering undergraduates. In an effort to attract and retain more engineering students, Tufts University implemented design-based courses required of all new engineering students. The course instructor of the first-year "Simple Robotics" course, one of the design-based courses offered for the entering freshman across engineering disciplines, structured the course consisting of a series of small-group projects throughout the semester with the goal of emphasizing a breadth of key technical and non-technical engineering areas. The open-ended design projects leveraged the LEGO MINDSTORMS EV3 robotics toolset as the hardware and the LabVIEW Graphical Programming Environment as the software. As a means of a) facilitating students in their reflection process and b) capturing research data on the evolution of student reflections over the course of a semester, the instructor administered a non-graded, open-ended survey at various points throughout the semester. Twenty-three students (four female and nineteen male) out of twenty-eight enrolled in the course consented to be included in this research study.

The following data and analysis will focus on the survey data collected after the first project of the semester and again after the final group project of the semester. The first project ("Robotic Animals") asked students to create a robot which mimicked an animal of the student's choosing to introduce the students to the hardware, software, and engineering design as they incorporated the use of inputs and outputs; the grading focused on the overall animal design (including the realism of the movements and actions), the construction and code, and quality of sharing during an in-class presentation. The final project of the semester ("Playful Creations") was use the skills and technologies explored throughout the semester to create an interactive toy experience designed for children aged 4 to 8 that would *support productive play, ideally through not limiting interactions with other children, leave space for imagination and creativity, and should be developmentally appropriate*. Grading for this project focused on general product design, construction, and code, as well as development of user-assessment survey (issued to children) and prototype iteration based on data collections (feedback from clients). Engineering students were provided two user-testing sessions with local children to obtain feedback on the toys and iterate on the designs.

Methodology and Data Coding

The motivation for this study is grounded in previous literature detailing the breadth of skills 21st century engineering students are expected to know and the disconnect students may experience in what is expected of them to succeed [12, 13]. Study analysis will thus consider emerging themes around skills/attributes that students associate with success and how these themes evolve as the student grows in their engineering experiences.

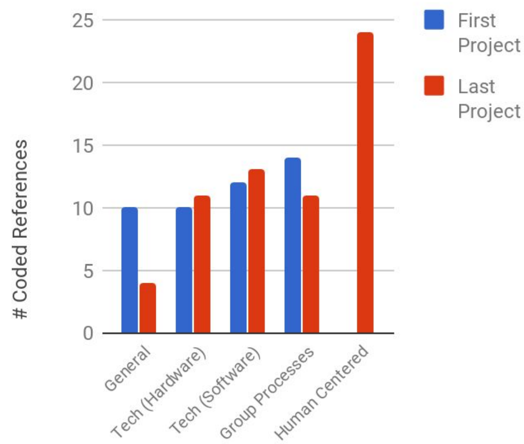
At various points throughout the semester, the same open-ended survey (6 reflection questions total) was administered to the students, and two of those questions will be the focused for this study. The first asked the students *"How successful did you feel in completing this project?"* while the second asked *"After completing this project, what would you have done differently? How might you change the way you do the next project?"* Examination/coding of the twenty-three student survey responses (by the instructor and two graduate researchers) led to the emergence of four major themes across their answers: general performance, technical competency (both hardware and software in nature), considerations for human-centered design, and group processes (see Table 1 of example student responses for each category).

Table 1: Coding Scheme Applied to Student Responses

Coding Scheme	Example Student Responses
General Performance	"We completed all the requirements", "did what we wanted it to"
Technical (Hardware)	"I would [rather have] use an armature and motors rather than a gyro sensor for arm location sensing."
Technical (Software)	"...We were able to get the steady control with some haptic feedback and wireless communication working, so I would label this as a success."
Human-Centered Design	"we got 6 stars, so it was great to hear that other people really liked our final game. "
Group Processes	"Yes, we spent a lot of time trying to decide what we were doing, how we were doing it, and how to present it, and it felt like it paid off...."

The "General Performance" category was needed to account for any vague student responses which were especially common in responses concerning the first project. "Technical" problems often were specific to the "Hardware" or "Software" aspects of the robotic implementation. Any identification of "Human-Centered Design" indicates a student's acknowledgement of the end-user and the role of user-testing in the design process. Finally, "Group Processes" were comments that involve any reference to the time management, goal setting, and general organization of the project team. A given response might contain more than one thematic references. It is also important to note that there are no “Human-Centered Design” references in the first project surveys, as that project (“Robotic Animal”) did not pose a client or specific end-user.

Figure 1: First Project vs Final Project Thematic Instances in Survey Questions



Student Survey Data

A first look at the data suggested that both at the start and finish of the semester, students had a definition of success that went deeper than simply technical attributes. Figure 1 illustrates the cumulative number of thematic references across both questions after the first project vs the final project.

A qualitative examination of the first project responses revealed that students tended to offer more generalized answers and lacked overall sophistication in their answers as compared to the reflections following the final project. For the first project, references to changes in technical attributes were largely centered around gaining individual experience in a particular software program or material (e.g.. “learn LabView” and “[would have] played around more with LEGO before starting the design”). In contrast, the final project response references to technical aspects indicated more specific implications for a future prototype (e.g. “[I want to] make the catapult be able to aim and shoot by itself. Maybe have it compete with the human player or something fun. Or figure out how to couple lego motors to give the catapult more strength.”). As can be seen in Figure 2, three students reported after the first project that there was nothing they would do differently, a response that did not occur at all after the final project. Both post-project “do different” questions revealed a very similar number of references in wanting to change technical and group processes aspects of the project; however, after the final project, the reference to group processes generally offered more specificities and were less grounded in time management than first project responses (see Table 2).

Figure 2: Breakdown of Responses for "What would you do differently?"

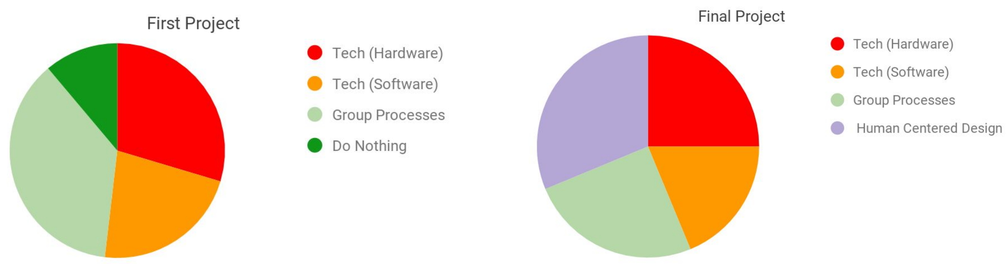


Table 2: Sample "Do Different" Responses with References to Changing Group Processes

After First Project	After Final Project
"Start earlier"	"Instead of jumping from project to project we should have made a list of all possible projects and then list their pros and cons and decide instead of starting on one project and ditching it half way."
"I would help take the initiative and try not to rely on [partner] so much. This way we probably would have finish earlier and so I could of help decorate the giraffe before I left for the weekend"	"I probably would have tried to make the group more collaborative and really get everyone to really get into the project. So for future projects it may be easier to assign specific tasks for each person to be accountable for."

Regarding the question of success, another major difference could be seen in how students referred to the project rubric. While both projects consisted of a rubric, which outlined the project and grading breakdown, only after the first project did any students specifically refer to the rubric as a metric in explaining their successes. Such references included "we were successful in following the rubric" and "we met all of the guidelines." If the general responses are disregarded, the first project contains a sum of just 12 engineering attribute references in comparison to the 26 references after the final project. Interestingly, all students across both projects who mentioned elements of group processes did so in a positive way; in other words, they partially attributed their project success to upfront organization, group planning, and/or good time-management. The references to the elements of technology, whether hardware or software, were divided as to whether these elements attributed to the shortfall of the project or to the project successes.

Discussion

While the specificities and depth of student responses varied across both projects, the results nevertheless revealed that students did see value in a breadth of technical to non-technical engineering attributes from the onset through to the completion of the course. This finding suggests that the instructor found at least some success in implementing a human-centered design project towards the end of the semester in a way that did not de-emphasize or neglect previously emphasized technical skills. The importance of technical soundness of the final product and the impact of group processes and communication were emphasized in both sets of project responses. However, responses from the first project revealed anecdotes that would be expected of a novice engineer, particularly in the lack of any suggestions for improving upon future iterations. Further, after the final project, several students were able to identify and acknowledge their own shortcomings in properly testing for a particular end-user or conducting adequate research on the end user. Those that found success largely attributed it to the positive feedback from their end users (the children) and the technological features of the toy they created that led to the children's positive responses.

Conclusions and Future Work

This research contributes to the growing body of literature around project-based first year engineering courses in its examination of how students view their own success in engineering. While these results are promising in their demonstration of first year students gaining an increased awareness and appreciation for a range of technical to non-technical engineering skills, it is important to acknowledge the small sample size of this study. Additionally, there are various other factors that may have potentially impacted student perceptions and growth in engineering that are beyond the scope of this paper to consider. For instance, other class assignments outside of the two described projects may have led to shifts in perceptions. It should also be acknowledged that the first project reflection occurred within only a couple weeks of the start of students' college experience, while students are still adjusting to the demands of university life and what is expected of them. Nevertheless, this research adds to the growing body of literature examining the impacts of project-based engineering courses on first year students. In future work, we will further explore the instructor's course design and implementation of all three course projects (each containing a unique set of objectives and context) and the trajectory of student self-assessment of their own learning throughout the course. Surveys evaluating future iterations of the course may additionally ask students to reflect upon their experiences outside of the classroom, as Kilgore has done [12], to gain better insight into students workflow and perceptions. Additionally, we hope to broaden this research to other First Year Design Courses at Tufts University.

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