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Assessment of Communication, Teamwork, and Engineering Motivation in Inter-Disciplinary Projects Implemented in an Introduction to Engineering Course

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Introduction

Inter-disciplinary project teams are a fact of engineering careers. Inter-disciplinary thought and action are required to solve many of today's technological and social challenges. Government reports such as Educating the Engineer of 2020[1], Facilitating the Interdisciplinary Research[2], and Rising Above the Gathering Storm[3], have also advocated that we prepare engineers that can work in interdisciplinary environments. While more and more institutions have incorporated multidisciplinary projects in the freshman introductory courses, many students are not exposed to inter-disciplinary team environments until their senior design project.

This paper will discuss the integration of inter-disciplinary teamwork into the Introduction to Engineering course at Arizona State University. More specifically, the implementation of a large real-world hands-on design project will be discussed, which consists of multidisciplinary teams from two sections of the course offered in Fall 2014 collaborating on designing, building, and testing autonomous waste sorters. Teams from one section of 38 mechanical, aerospace, electrical, and chemical engineering students are paired with those of the other section with 43 computer science, informatics, software engineering, computer systems engineering, industrial engineering, and engineering management students. While the teams from each section focus on different aspects of the design, inter-disciplinary collaboration and system integration is required for a successful final product.

The impact of this experience on students' knowledge and self-efficacy of the engineering design process, their technical communication skills, and teamwork has been measured. A survey instrument adapted from the APPLES (academic pathways of people learning engineering) survey[4] and the study of measuring engineering design self-efficacy[5] was administered before the start of the hands-on design project and again at the end of the semester after the completion of the design project to over 80 students in both sections of the course. The purpose of the survey is to better understand the value of the inter-disciplinary teams in the introduction to engineering classroom. Results from the survey are used to determine the impact of this experience and are presented.

Course Description

At Arizona State University, the introduction to engineering course is a 2 credit multidisciplinary course with a 50-min lecture and a 3-hour lab each week offered over a 15-week semester. Four versions of this course are offered to over 2,000 freshmen engineering students each fall in small sections of 40-43 students. The authors each teach a few sections of a different version of this course (with the same learning outcomes and course structure), with one version being offered to mechanical, aerospace, electrical, and chemical engineering students and another to computer science, informatics, software engineering, computer systems engineering, industrial engineering, and engineering management students. This course focuses on the engineering design process, teamwork, communication skills, as well as other basic engineering skills and tools; and contains a large "hands-on" team based project. The design process, engineering basics, skills and tools are introduced during the first 7 weeks of the course and the later 8 weeks are used for the team based design project. The design project is usually designed and implemented (or selected) by the instructor based on the disciplines involved, and it aims at providing students with the opportunities to apply the design process with design iteration and solve a real-world related engineering problem in a multidisciplinary team environment.

Study Methodology

This study is used to understand the impact of the inter-disciplinary collaboration between teams implemented through an inter-disciplinary project in an introduction to engineering course. Teams with different backgrounds and from different disciplines were required to collaborate through the inter-disciplinary hands-on design project. Students in several sections of this introductory engineering course were involved in the study. The Experimental group consisted of two sections of the course – one section consisting of student teams from mechanical, aerospace, electrical and chemical engineering majors (henceforth collectively referenced as "Mechanical" disciplines), partnering with student teams from one section consisting of computer science, informatics, software engineering, computer systems engineering industrial engineering, and engineering management majors (henceforth collectively referenced as "Computing" disciplines). The cross-discipline project given to these sections was the "Autonomous Waste Sorter Project" described below. Two sections of control group students in Mechanical disciplines participated in a "Grand Challenges Project" described below, and two sections of control group students in Computing disciplines participated in a "Lego Maze Robot Project" described below.

Experimental and Control group students were evaluated over one 15-week semester. Lectures throughout the semester and assignments at the beginning of the semester were identical for all students involved in the study, so that the only difference between experimental and control groups was the large project, spanning the later 8 weeks of the semester. To collect data, all students involved in the study were asked to complete a survey instrument twice (see Appendix A for survey details): once during the first 3 weeks of the semester (before students started to work on the projects), and again during the last week of the semester after students have completed the projects and had the teamwork experience. Additionally, final grades of students in the Computing disciplines were collected. Measured outcomes included self-efficacy of technical communication, teamwork, and knowledge of the engineering design process.

Project Descriptions

Students assigned the inter-disciplinary "Autonomous Waste Sorter Project" were asked to design and construct a device that can autonomously sort recyclable materials. Sortable materials included metal, glass, paper and plastic objects of various sizes and shapes. Student teams were required to design a device to sort metals (either steel or aluminum), glass (clear, green or brown), paper, and plastic. Extra credit was awarded to teams whose device could successfully sort different types of metals (distinguishing between steel and aluminum) and different colors of glass. Students in the Mechanical disciplines were tasked with designing and constructing the physical components of the project, while students in the Computing disciplines were tasked with designing and programming the control system of the project. Teams across the disciplines were strongly encouraged to communicate and coordinate with each other to achieve device functionality. Team collaboration and system integration were mostly done outside of class. Device performance was evaluated by observing the accuracy of material separation, cost, creativity of design, and craftsmanship and aesthetics. Deliverables for this project included a project schedule, a project definition and requirements document, a design proposal presentation and report, design prototype presentation with demonstration, and a final design report.

Students assigned the Computing disciplines "Lego Maze Robot" project were asked to design and program a Lego Mindstorms ™ robot to autonomously navigate a simple maze. Students were evaluated on maze completion, time to complete the maze, and design creativity. Deliverables for this project included a project schedule, project definition and requirements, a design proposal report, design presentation with demonstration, and a final design report.

Students assigned the Mechanical disciplines "Grand Challenges" project selected one of three design problems, each aligned with one of the fourteen NAE Grand Challenges for Engineering identified by the National Academy of Engineering (the complete list is available at the NAE Grand Challenges for Engineering website[6]). The design problems involved designing and constructing a solar tracking device, a water transportation and filtration device, and an educational toy/exhibit, respectively. Students were evaluated on performance of the design (based on quantitative results), cost, creativity of design, and craftsmanship and aesthetics. Deliverables for this project included a project schedule, project definition and requirements, a design proposal presentation and report, design prototype presentation with demonstration, and a final design report.

Results

The first three questions in the survey instrument requested information about the academic status of the student population, and their level of college experience. Figure 1 shows that the surveyed population is primarily composed of students with freshman level academic standing and few upper level students.

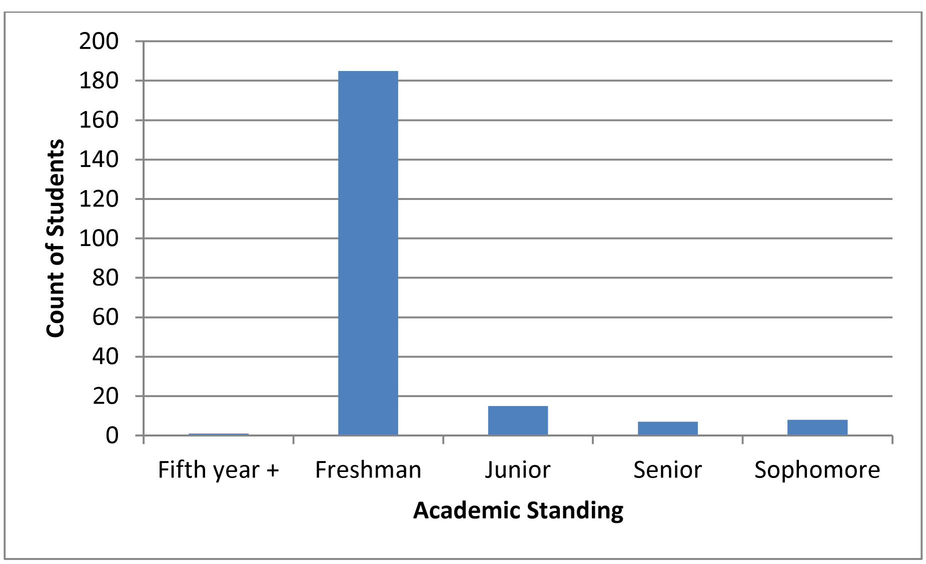

Fig. 1 – Count of current academic standing of surveyed population.

The surveyed population is also significantly first-time college students, as shown in Figure 2. This is a common demographic for fall semester Introduction to Engineering students at our institution.

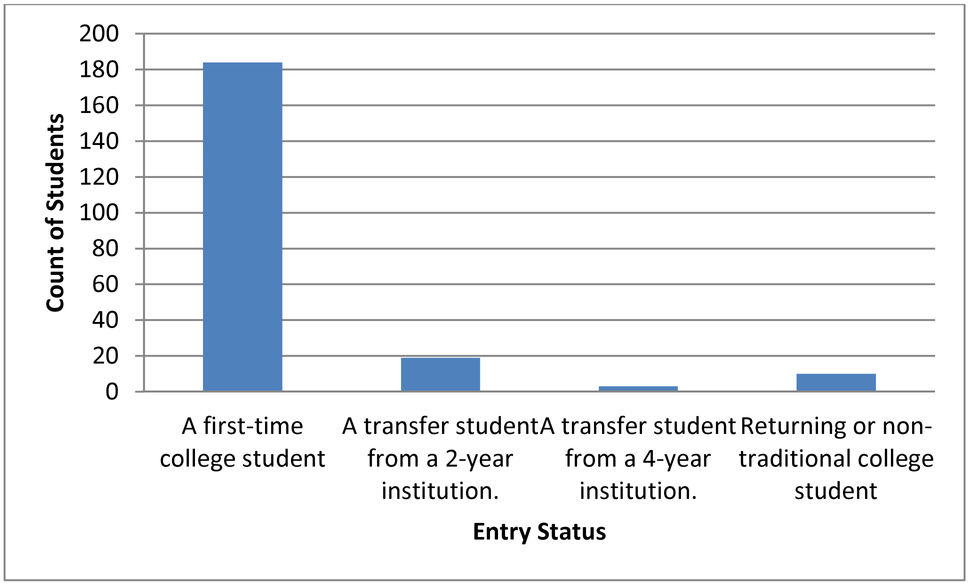

Fig. 2 – Count of college entry status of surveyed population.

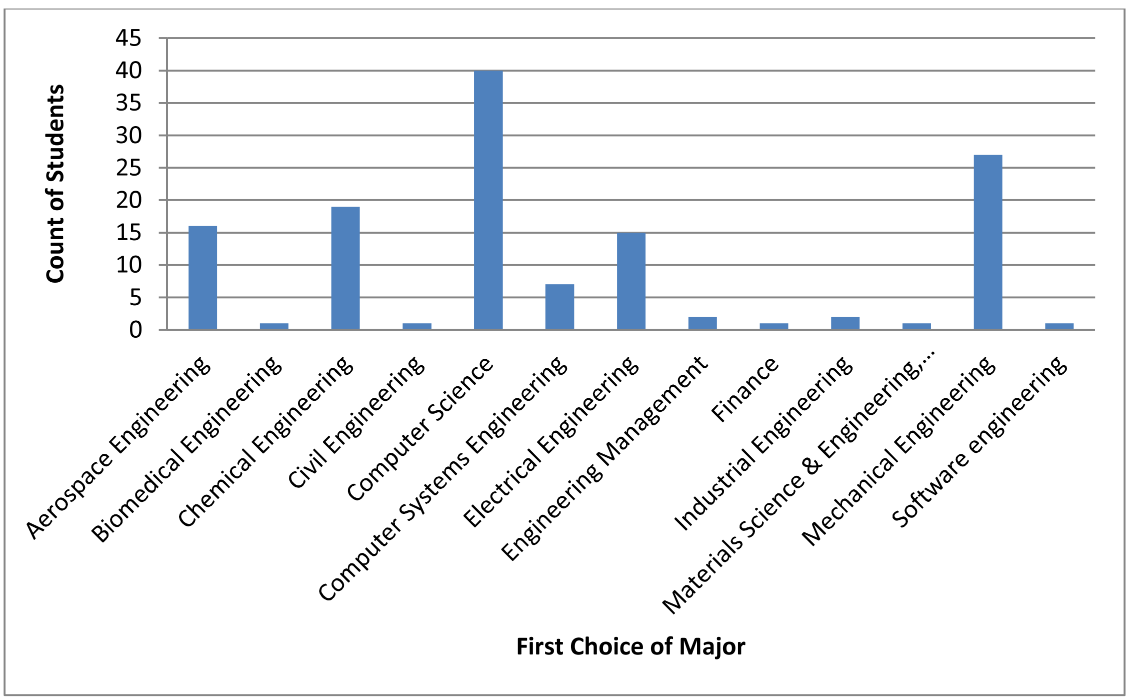

Fig. 3 - Count of students by selected first choice of major in survey population.

The surveyed population is significantly composed of individuals with computer science as a first choice of major, followed by mechanical engineering, chemical, aerospace, and electrical engineering (Figure 3). This is likely due to the fact that the study was conducted in these departments, and not in all engineering departments at the institution.

Figure 4 shows the distribution of major choice among the different projects evaluated in this study. The Lego Maze Robot Project was primarily composed of computer science majors, while the Grand Challenges Project was composed of a mix of mechanical, aerospace, chemical and electrical engineering students. The distribution of majors in the Autonomous Waste Sorter project shows that there is nearly parity between the computing related majors and non-computing majors in the surveyed population.

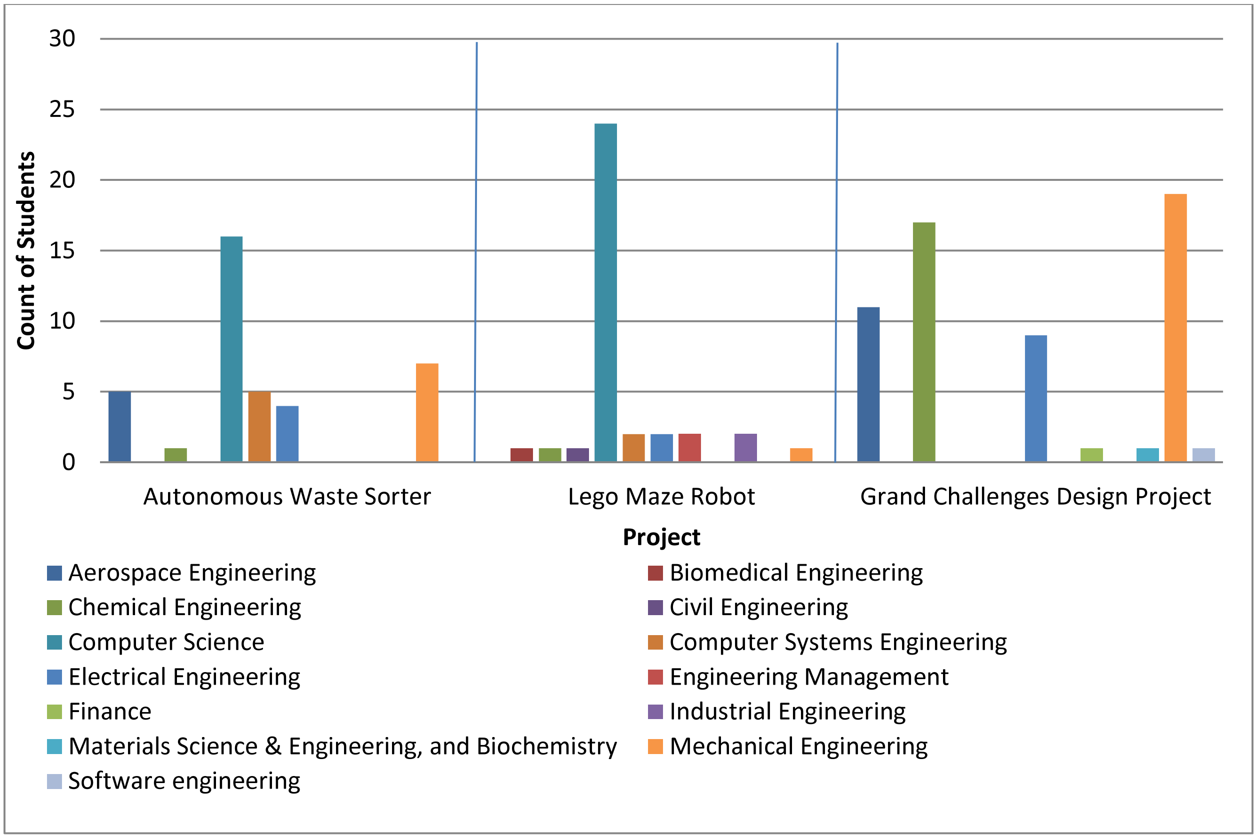

Fig. 4 – Distribution of majors to each project in surveyed population.

In most of the following questions in the survey, it appears that most students marked the same values in each group of questions, so there is very little variation between questions sub-categories. In the interest of brevity, the response categories are compressed so that each bar shows the response for multiple questions, only if they are all the same for all questions in the category. Error bars on the graphs show 95% confidence intervals.

The next group of questions in the survey instrument requested information about why students were interested in studying engineering. Shown in Figure 5, the responses to these questions were broken down by responses given by the survey at the start of the semester ("Pre-Survey") and responses given at the end of the semester, further broken down by which project the students participated in. For this and all following results, statistical significance was determined using single-factor analysis of variance with a $\alpha < 0.05$ confidence. We can see that all 3 projects had significant impact with respect to the pre-survey results but only the Grand Challenges Project had significantly different impact from the Autonomous Waste Sorter Project. Mean for pre-survey questions is between 3.35 and 3.37. As for post-survey, for the Autonomous Waste Sorter Project mean for the questions is between 3.54 and 3.58; and it is between 3.09 and 3.13 for the Grand Challenges Project; and 3.43 and 3.49 for the Lego Maze Robot Project. Thus, both the Lego Maze Robot Project and the Autonomous Waste Sorter Project have had a positive impact on students' interests in studying engineering while the Grand Challenges Project had a negative impact.

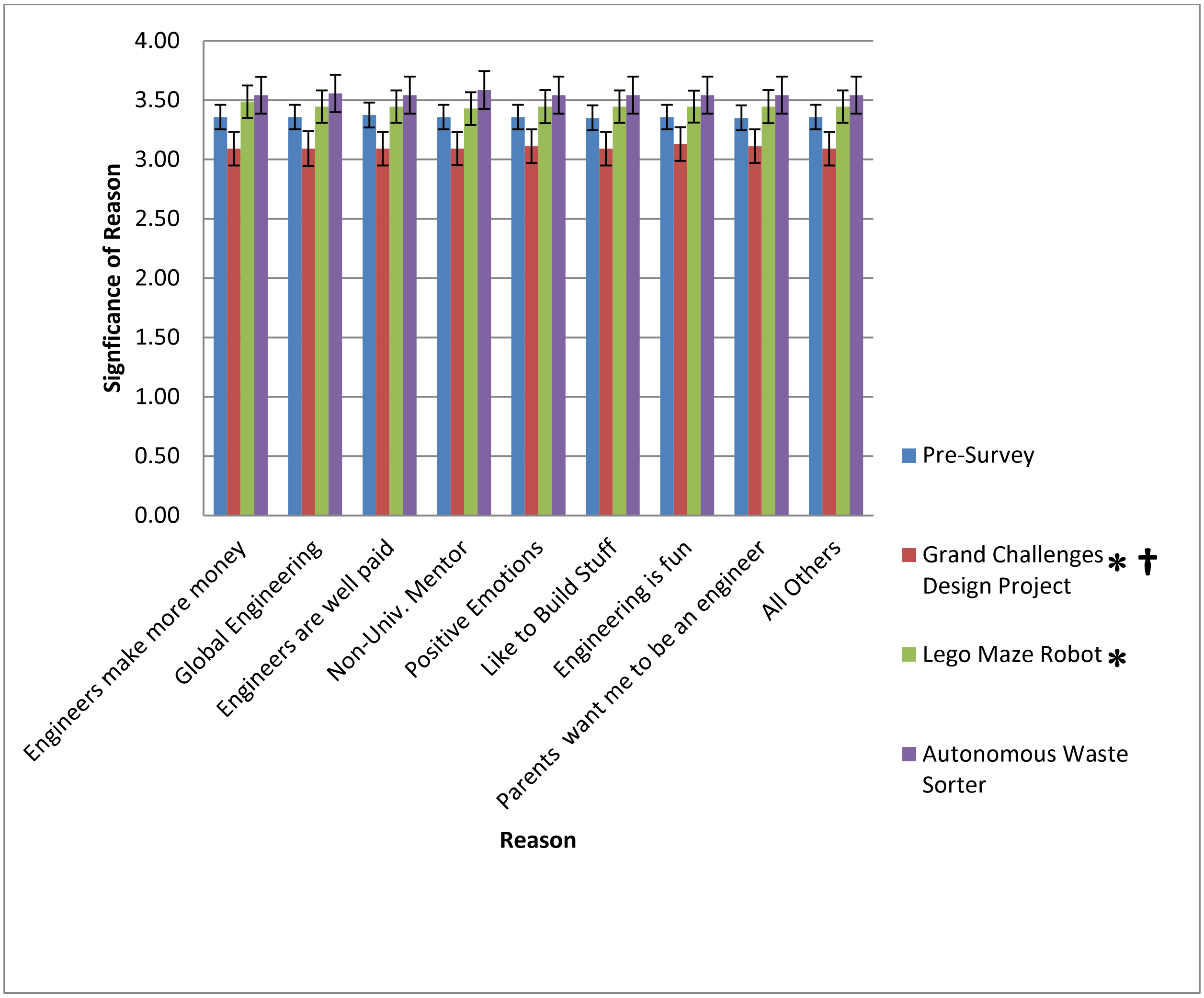

Fig. 5 – Survey results of reason for entering engineering study, pre-survey and post-project. Scale is from 1 (Not a Reason) to 4 (Major Reason). The "All Others" category shows responses from "Importance Society", "Parents Disapprove of other disciplines", "Job Opportunities," "University Mentor", "Met People in Field," "Positive Social Impact", "Interesting," and "Figure out how things work," which all had identical values.

∗ - All responses to this question were significant with respect to the pre-survey results.

† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

Survey respondents were also asked to self-identify with characteristics commonly associated with engineering. These results are shown in Figure 6, where it can be seen that only the Lego Make Robot project had significant impact on self-identification characteristics, with respect to both the pre-survey and the Autonomous Waste Sorter Project. Thus, only the Lego Maze Robot Project changed students' self-identification characteristics while neither the Grand Challenges Project nor the Autonomous Waste Sorter Project did.

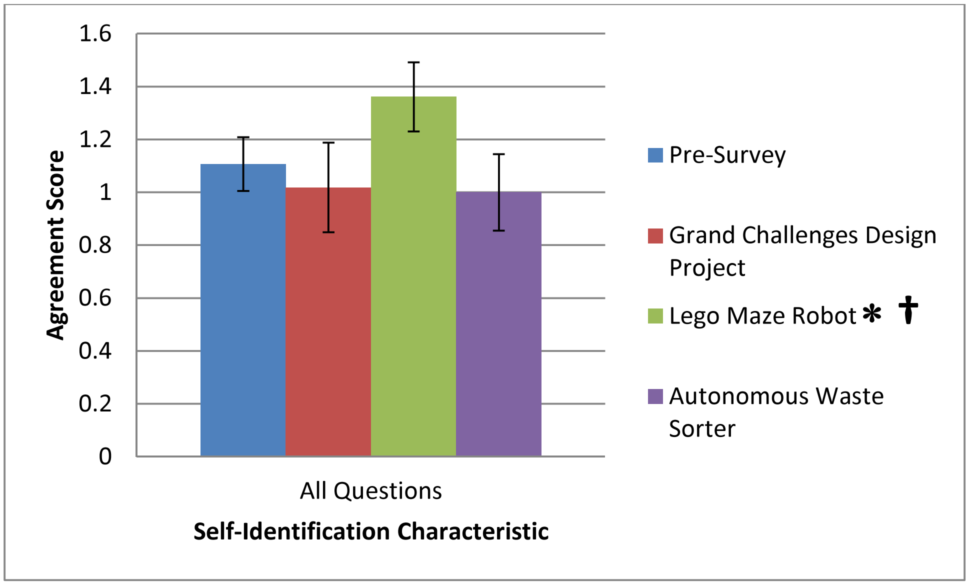

Fig. 6 – Survey results of self-identification characteristics, pre-survey and post-project. Scale is from -2 (Strongly Disagree) to +2 (Strongly Agree). All responses to this question group had identical response values.

* - All responses to this question were significant with respect to the pre-survey results.

† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

Next, participants were asked to evaluate their skills relative to their classmates, results shown in Figure 7. The Grand Challenges Design project and the Lego Maze Robot Project both had significant impact on self-evaluated skills with respect to the Pre-Survey, but only the Lego Maze Robot had significant impact with respect to the Autonomous Waste Sorter project. Thus, after completing the Grand Challenges Project and the Lego Maze Robot Project, both groups of students considered that their engineering related skills had improved compared to their peers, while students who completed the Autonomous Waste Sorter Project did not think that their skills improved compared to their peers.

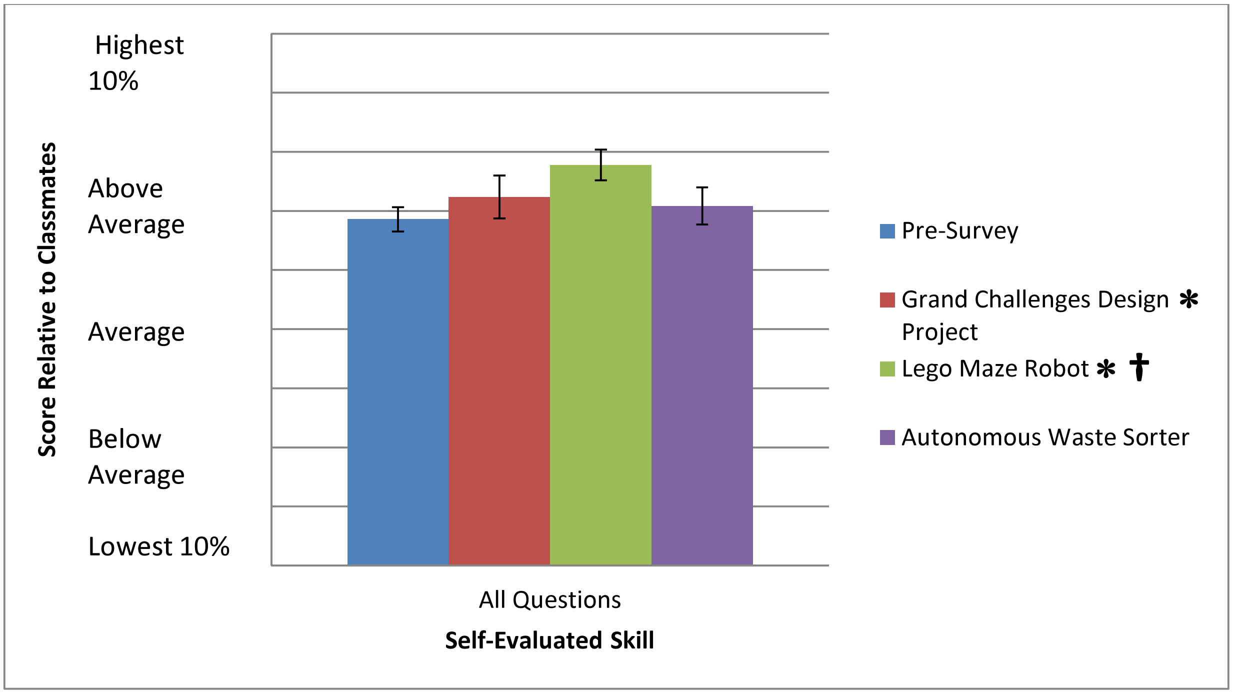

Fig. 7 – Survey results of skills relative to classmates, pre-survey and post-project. Students were asked to rate themselves relative to their classmates. Scale is from 1 (Lowest 10% of classmates) to 9 (Highest 10% of classmates). All questions in this response category had identical values.
∗ - All responses to this question were significant with respect to the pre-survey results.
† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

Question 9 of the survey requested participants to rate the importance of skills to becoming a successful engineer, results shown in Figure 8. In these results, only the Autonomous Waste Sorter project shows significant impact with respect to the pre-survey, and both the Lego Maze Robot and Grand Challenges Design Projects results are significant with respect to the Autonomous Waste Sorter. Thus, only the Autonomous Waste Sorter Project changed students' perception of the importance of all skills listed in the question to engineers. This group of students considered these skills to be more crucial to engineers after completing the project.

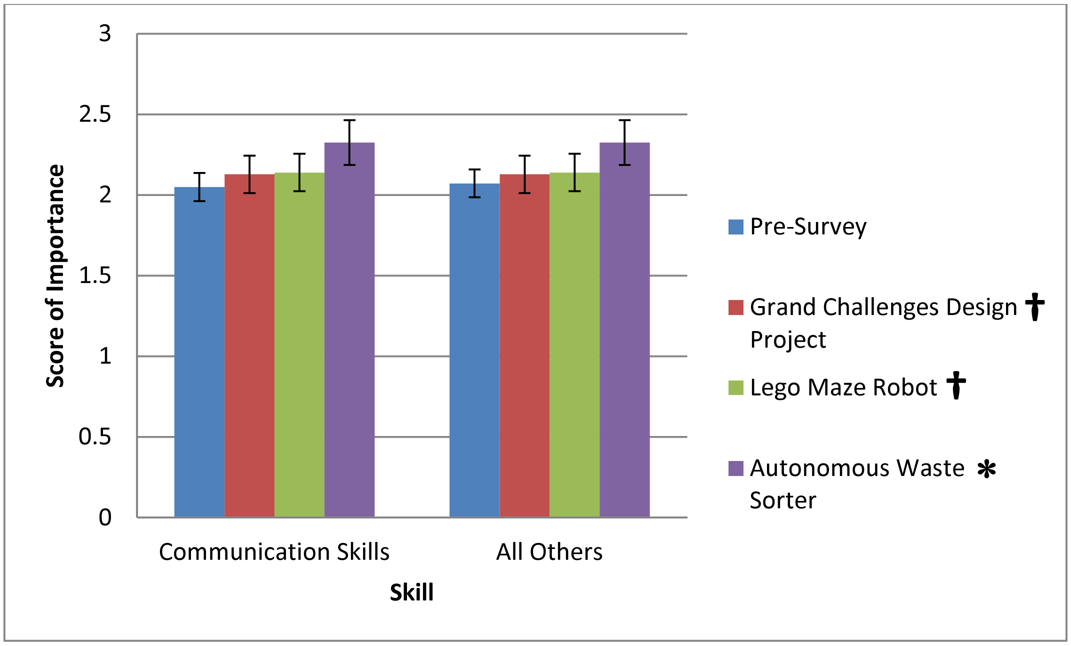

Fig. 8 – Survey results of importance of skills in engineering, pre-survey and post-project. Scale is from 0 (Not Important) to 3 (Crucial). The "All Others" group represents responses from the "Leadership Ability," "Public Speaking Ability," "Math Ability," "Science Ability," "Ability to Apply Math & Sci.," "Business Ability," "Teamwork Ability," and "Critical Thinking Skills," categories which all had identical values.

* - All responses to this question were significant with respect to the pre-survey results.
† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

Question 10 asked participants to evaluate their confidence in executing engineering activities, shown in Figure 9. In these results, almost all results are significant with respect to both the pre-survey, and the Autonomous Waste Sorter Project Results. Thus, all three projects had positively improved students' confidence in performing engineering design in general, including activities such as, conduct engineering design, identify a design need, develop design solutions, select the best design, etc. Out of the three projects, the Lego Maze Project had the largest impact, while the Grand Challenge Project had the smallest impact.

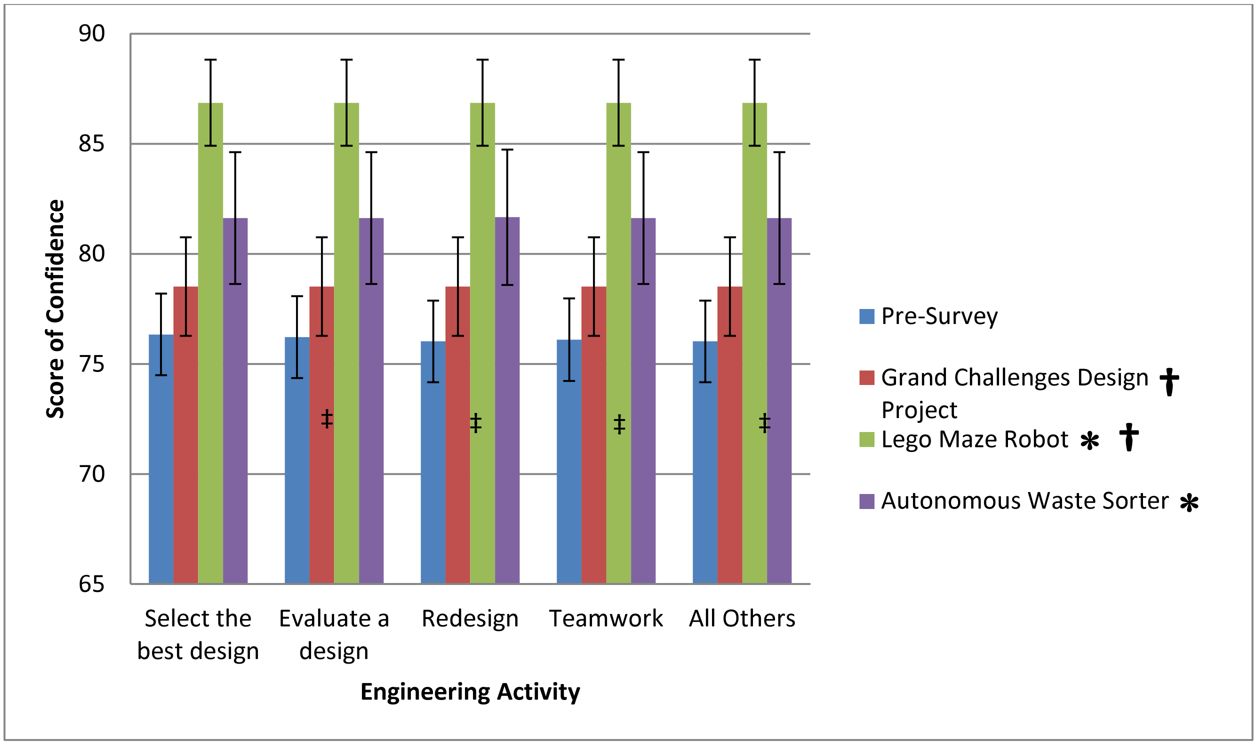

Fig. 9 – Survey results of self-confidence in executing engineering activities, pre-survey and post-project. Scale is from 0 (cannot do at all) to 100 (highly certain can do.) The "All Others" category includes responses from "Conduct Engineering Design," "Identify a design need," "Research a design need," "Develop design solutions," "Construct a prototype," and "Communicate a design" which all had identical values.

* - All responses to this question were significant with respect to the pre-survey results.
† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.
‡ - Responses to this question were significant with respect to the pre-survey results.

Question 11 asked participants to evaluate their motivation in executing engineering activities, shown in Figure 10. In these results, only the Grand Challenges Design project results are significant, with respect to both the pre-survey results and the Autonomous Waste Sorter project. Thus, neither the Autonomous Waste Sorter Project nor the Lego Maze Robot Project had positively improved students' motivation in performing engineering design in general, including activities such as, conduct engineering design, identify a design need, develop design solutions, select the best design, etc. While the Grand Challenge Project had a negative impact.

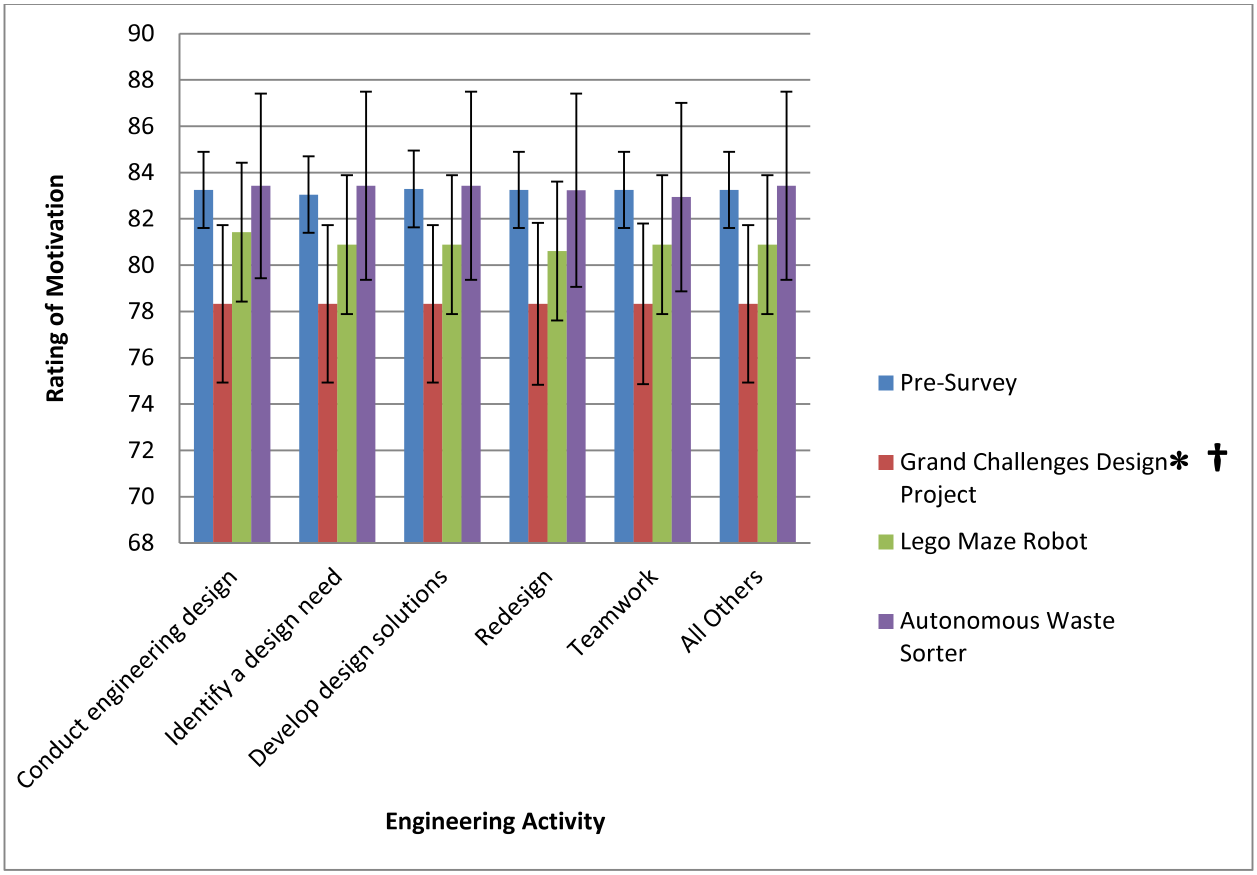

Fig. 10 – Survey results of motivation to execute engineering activities, pre-survey and post-project. Scale is from 0 (Not motivated at all) to 100 (highly motivated.) The "All Others" category includes responses from "Research a Design Need," "Select the best design," "Construct a prototype," "Evaluate a design," and "Communicate a design" which all had identical values.

∗ - All responses to this question were significant with respect to the pre-survey results.
† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

Question 12 asked participants to evaluate their expectation of success in completing engineering activities, shown in Figure 11. In these results, the results indicate that all 3 projects had significant effects with respect to the pre-survey, but no significant differences between them. Thus, after completing the project, students in each group all expected to a similar extent that they would be much more successful in completing engineering design in general, including activities such as conduct engineering design, identify a design need, develop design solutions, select the best design, etc.

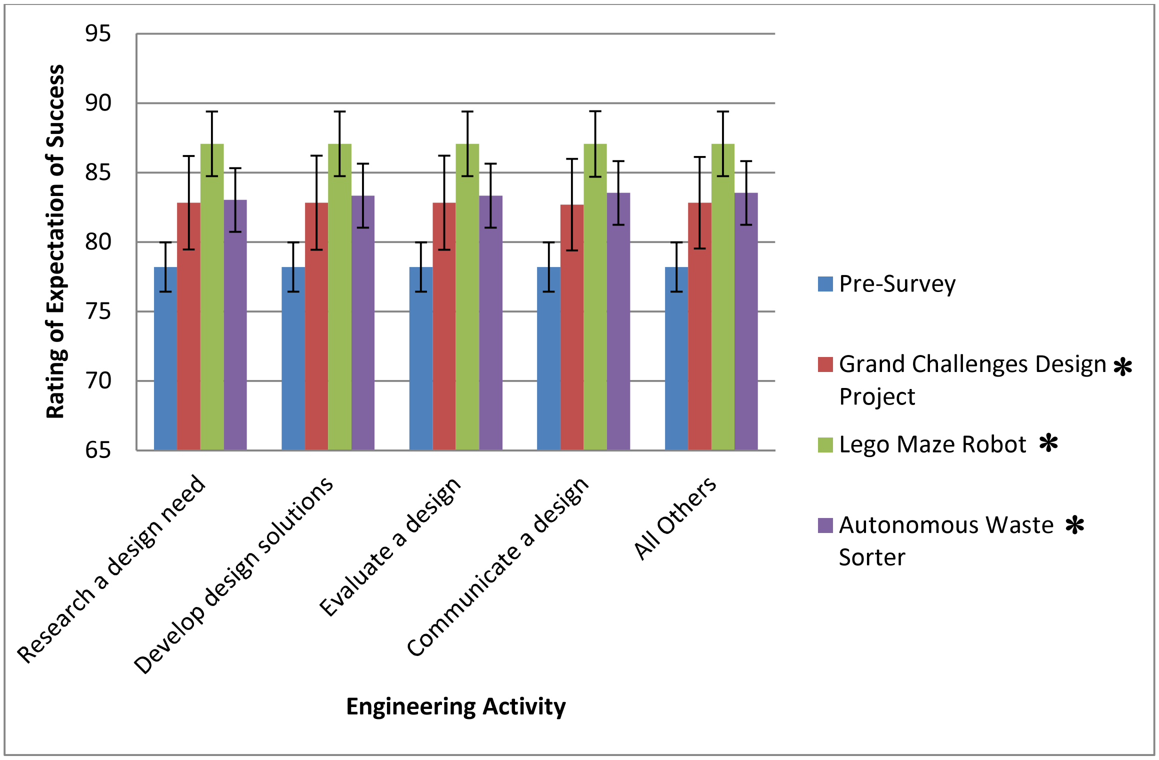

Fig. 11 - Survey results of expectation of success in executing engineering activities, pre-survey and post-project. Scale is from 0 (not successful at all) to 100 (highly successful). The "All Others" category includes responses from "Work as part of a team," "Conduct engineering design," "Identify a design need," "Select the best design," "Construct a prototype," and "Redesign," which all had identical values.

* - All responses to this question were significant with respect to the pre-survey results.
† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

Question 13 asked participants to evaluate their level of anxiety in performing engineering activities, shown in Figure 12. The results indicate that none of the projects had significant effects with respect to the pre-survey, but the Grand Challenges Design project effects are significantly different from the Autonomous Waste Sorter design project. Thus, none of the three projects changed students' level of anxiety in performing engineering design related activities, such as conduct engineering design, identify a design need, develop design solutions, select the best design, etc. However, compared to students who completed the Grand Challenge Project, those who completed the Autonomous Waste Sorter Project had a higher level of anxiety in performing engineering design in general.

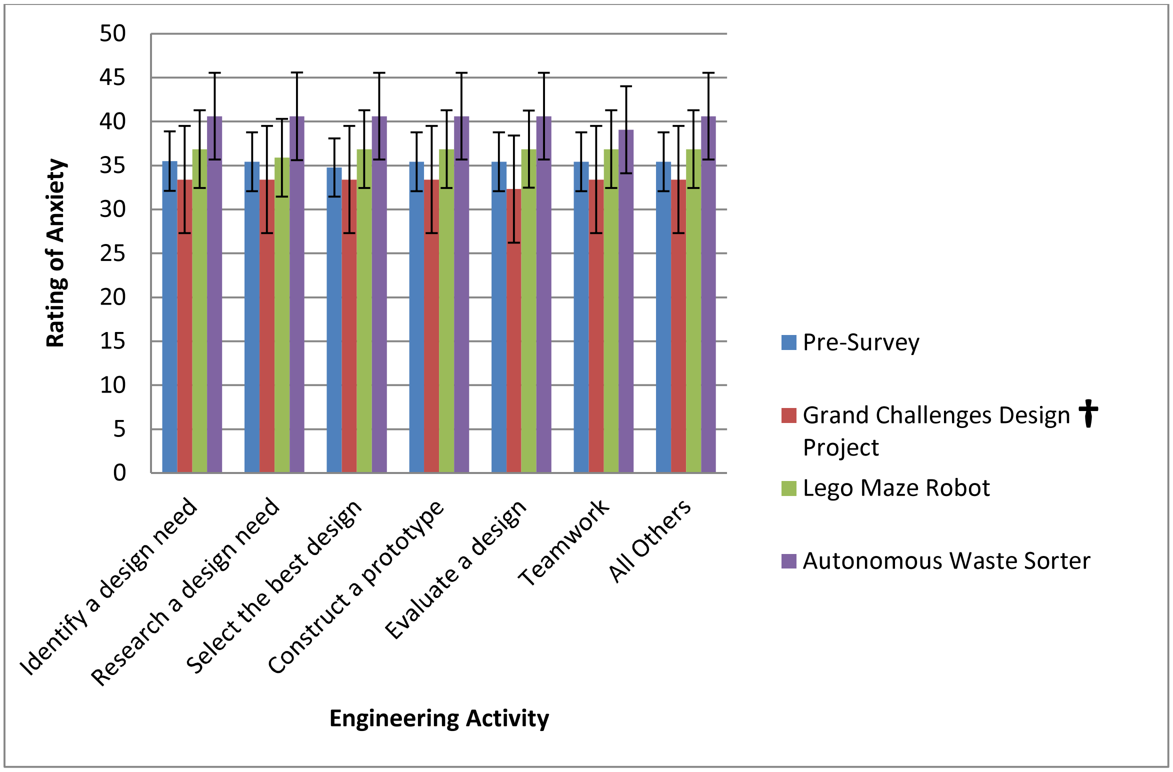

Fig. 12 - Survey results of anxiety to execute engineering activities, pre-survey and post-project. Scale is from 0 (no anxiety at all) to 100 (highly anxious). The "All Others" category includes responses from "Redesign," "Conduct engineering design," "Develop design solutions," and "Communicate a design" which all had identical values.

∗ - All responses to this question were significant with respect to the pre-survey results.
† - All responses to this question were significant with respect to the Autonomous Waste Sorter Project results.

To evaluate the experimental project on learning outcomes, the grades on a pre-project assignment, and the final project grade were used as comparisons. This data was only able to be collected in the computing discipline groups, and is shown in Figures 13 and 14. Analysis shows that no significant difference was present between the two groups, on either the pre-assignment or final project grades.

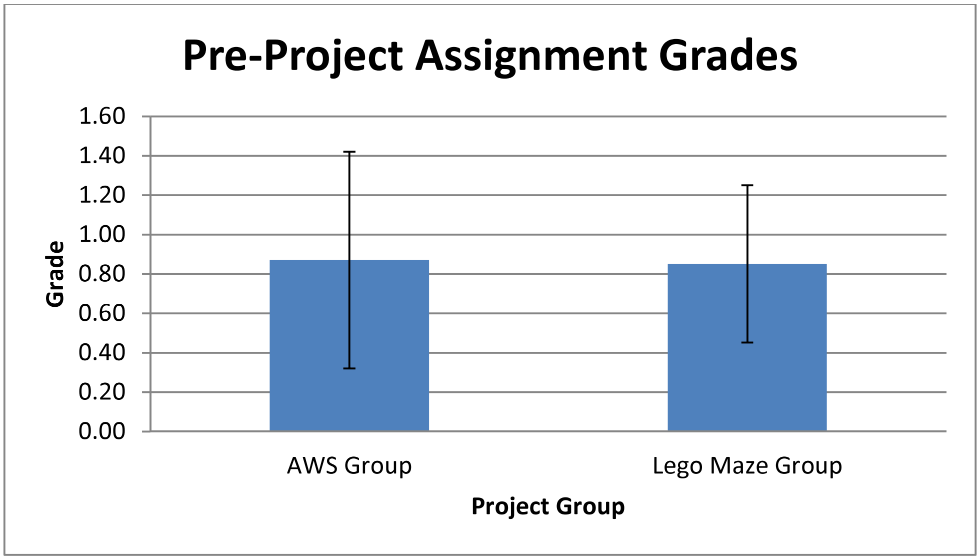

Fig. 13 – Comparison of Grades between Computing discipline project groups on a common assignment, before the experimental factor of the semester project differences were introduced. No significant difference was measured.

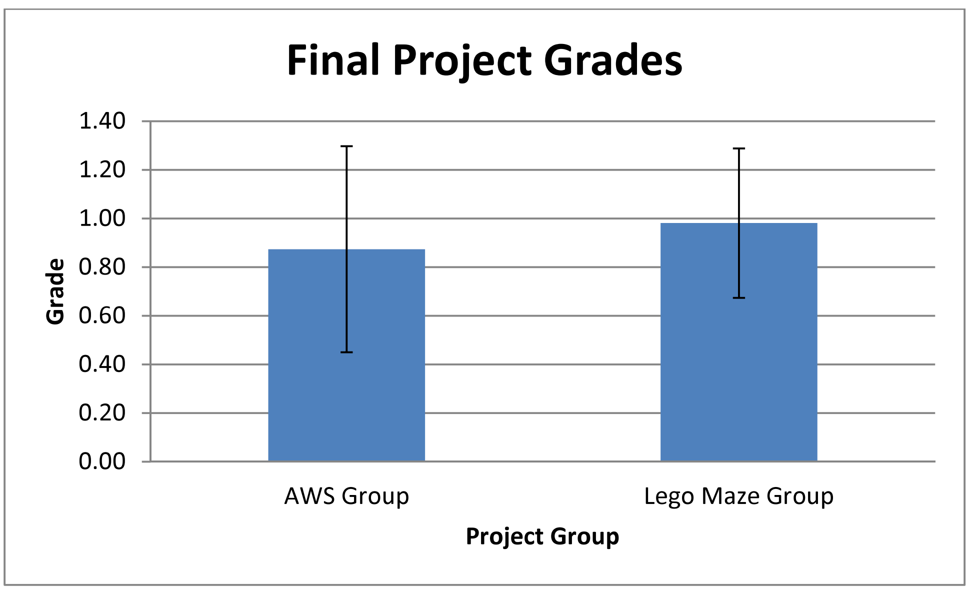

Fig. 14 - Comparison of grades between computing discipline project groups on final project assignment, after the experimental factor of the semester project differences were introduced. No significant difference was measured.

These survey results show that the inter-disciplinary project which required communication and collaboration between two multidisciplinary teams as well as the Lego Maze Robot project in achieving the course learning outcomes. The results also suggest that for these first-time college freshman engineering students, mostly majoring in Computer Science, Mechanical, Aerospace, Electrical, and Chemical Engineering, a hands-on team design project implemented in their first college engineering course had a positive impact on their self-evaluation and perception of skills that are important for engineers; their self-identification as an engineer; and their self-efficacy of engineering design. In general, this interdisciplinary project had a greater impact on these measured outcomes than the Grand Challenges project did, but it did not perform as well as the Lego Maze Robot project (reasons are discussed below). However, it did have a significantly larger impact on students' perception of the importance of all of the engineering skills out of all three projects.

The difference of the scopes as well as the levels of complexity of the two projects may have contributed to the better performance of the Lego Maze Robot design project. The Lego Maze Robot design project is challenging yet at an appropriate level for a specific group of students to accomplish (the computing disciplines), while the Autonomous Waste Sorter design project was adapted from the 2010 ASME (American Society of Mechanical Engineers) Student Design Competition (details are available at the ASME webiste[7]), which involves technical background normally found in junior and senior level courses and thus participant teams of a national student design competition like this normally consisted of at least a few upper-class students[7]. Such a design project, implemented in an introduction to engineering course for first-time college freshman engineering students during eight 3-hour labs, poses a greater challenge. Out of the ten teams (each consisted of a team from the computing disciplines and one from the mechanical disciplines) that participated in this design project, five (50%) had a successful working prototype. The other five teams either only solved part of the design problem, or had challenge successfully implementing their design ideas. For one, even though fundamentals of embedded systems, programming, electrical circuits, motors/servos, and mechanisms/robotics were introduced to students, they may still have a lack of sufficient technical background and experience needed to implement this real world design challenge. For another, extensive cross-team communication and collaboration was required and it was mostly done outside of the class. Each sub-team had specific background knowledge and clear communication was required about design specifications, as well as input and output from both sides for successful system integration. Such a challenge, though did not perform as well as one of the discipline-specific project on improving students' engineering design self-efficacy, did give students a clear idea about how the different skills (self-confidence, leadership, public speaking, math & science knowledge and implementation, communication, business, teamwork, and critical thinking) were all important in addressing complicated real world challenges. This could serve as an important motivator for students' success in future engineering courses as well as other activities through which these skills could be practiced/acquired. The long-term impact of this inter-disciplinary project could be investigated for future work.

Limitations of the Study and Future Work

In this study, three different projects were used, each given to a group of students with an appropriate background. The Control group in this study could consist of inter-disciplinary teams (team of Mechanical disciplines partnered with that of Computing disciplines) working on the Lego Maze Robot Project and the Grand Challenges Project. However, the authors each teach a different version of this course, offered at different times. Coordination between sections would become very difficult if inter-disciplinary teams have been used for all three projects. In addition, if an inter-disciplinary team had been given either the Lego Maze Robot Project or the Grand Challenges Project, a sub-team (either the one of Mechanical disciplines or the one of Computing disciplines depending on the project) may have limited contribution to the project as either of these two projects is heavily discipline-focused. And the inter-disciplinary team collaboration may be of limited value.

On the other hand, the same project, i.e., the "Autonomous Waste Sorter Project" could be given to both Experimental group and Control group, so that the only variable in the study is whether or not the inter-disciplinary collaboration between teams is present. However, practically speaking this is very difficult to implement. The authors each teach a different version of this course, offered to students with a very different background. The Autonomous Waste Sorter project is more vigorous than the other two projects and it requires knowledge and skills from different disciplines. If this project were offered to each section of the Control group, with either only Computing disciplines or only Mechanical disciplines, it will be very difficult for either section of students to complete within this freshmen level 2-credit course. Thus, three different projects have been used in this study and the differences in project may have an effect on the results. However, these projects have been carefully designed such that they all cover the same objectives, i.e., provide students with the opportunity to:

- Develop problem statements and design criteria/requirements by evaluating a project scenario using design techniques;
- Construct detailed project plans using basic project management techniques (such as scheduling and budgeting) and methods (such as Gantt charts);
- Use the engineering design process to design, create, and evaluate a prototype that addresses realistic design constraints and requirements, in a design team;
- Apply basic teaming principles (such as the Tuckman's Model) and team effectiveness practices while working with their teams;
- Write a technical report and give an oral/multimedia presentation following the course technical communication guidelines which include formatting, explaining and justifying aspects of the project.

In addition, the same set of project deliverables are designed and used for all three projects. These deliverables include problem definition and requirements, project schedule, project proposal presentation and written documentation, progress report memo, final presentation and demonstration, and final report.

For some of the survey questions, for example, questions 10-13, most students who completed the survey selected the same answer to all sub-categories in each question and thus very little variations were shown in the survey results for each of these questions. For example, when students are asked to rate their confidence to perform the following tasks by selecting a number between 0 and 100, conduct engineering design, identify a design need, research a design need, develop design solutions, select the best possible design, construct a prototype, evaluate and test a design, communicate a design, redesign, work as part of a team, most students selected the same score for each task (they clicked down the line for each grid question). This is possibly due to the fact that all survey questions were presented on one page via google forms and the survey was given to students at the beginning of labs each time using about 10 minutes. Students might have been overwhelmed by the amount of questions included and thus did not carefully differentiate between different tasks in each question. Because of this, this study cannot be used to draw conclusions for a specific design related task/activity. Rather, for survey questions 10-13, conclusions are only given about engineering design in general.

As future work, the Autonomous Waste Sorter project should be redesigned and properly scoped so that it is more appropriate for freshmen engineering students. A further study of the following two scenarios could be conducted to gain full understanding of the impact of inter-disciplinary project and team collaboration implemented in an introduction to engineering classroom: 1) same Experimental and Control groups are used and the Autonomous Waste Sorter project (after it has been properly scoped) is given to both groups; 2) both Experimental group and the Control group involve the inter-disciplinary team collaboration and the Experimental group is given the Autonomous Waste Sorter Project while two sub-groups within the Control group are each given the Lego Maze Robot Project and the Grand Challenges Project, respectively. Results from each scenario could be correlated. And students' performance and success in the long term could be tracked and studied. In addition, the survey could be better designed such that only one question is shown to students at a time (on a separate page) and more time should be given to students to complete the survey so that they may slow down and spend more time to think carefully about each of the following the engineering activities, i.e., conduct engineering design, identify a design need, research a design need, develop design solutions, select the best possible design, construct a prototype, evaluate and test a design, communicate a design, redesign, work as part of a team.

Conclusion

An interdisciplinary hands-on design project has been implemented in an introduction to engineering course, which required collaboration between a mechanical-focused multidisciplinary team and a computing-focused one. The impact of this design project on communication, teamwork, and students' engineering design self-efficacy was studied by surveying three groups of students both before and after their completion of a design project. One was given the experimental interdisciplinary project whereas the other two were each given a discipline-specific project. Pre- and post-project results suggest that the interdisciplinary project had a positive impact on the measured outcomes. The interdisciplinary project had a greater impact on measured outcomes than one of the other two projects. It also has changed students' perception of the importance of various skills in engineering and their expectations of engineering in action in the real world to a greater extent, which may have a long-term impact on their success in engineering. Further research is needed to study these long-term impacts.

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[6] National Academy of Engineering Grand Challenges for Engineering. http://www.engineeringchallenges.org/cms/challenges.aspx

[7] American Society of Mechanical Engineers Student Design Competition. https://www.asme.org/events/competitions/student-design-competition

Appendix A – Survey Instrument

1. Enter an anonymous username. Your username should be the first 2 letters of you middle name, the first 2 letters of your mother's maiden name, and two numbers of the day you were born.

____

2. Which project did you work on this semester? (This question only given at end of semester)
   - Autonomous Waste Sorter
   - Lego Maze Robot
   - Grand Challenges Design Project

3. What is your current academic standing?
   - Freshman
   - Sophomore
   - Junior
   - Senior
   - Fifth year senior or more
   - I prefer not to answer
   - Other: ________________

4. When you entered this institution were you:
   - A first-time college student.
   - Returning or non-traditional college student.

- A transfer student from a 2-year institution.
- A transfer student from a 4-year institution.
- A transfer student that participates in a 3+2 engineering program.
- I prefer not to answer.

5. What is your current first choice of major? (Mark one)
   - Aerospace Engineering
   - Chemical Engineering
   - Civil Engineering
   - Electrical Engineering
   - Industrial Engineering
   - Mechanical Engineering
   - Computer Science
   - Computer Systems Engineering
   - I prefer not to answer.
   - Other: ______________

6. We are interested in knowing why you are or were studying engineering. Please indicate below the extent to which the following reasons apply to you:

(For each of the items below, survey participants selected one of: "Not a Reason," "Minimal Reason," "Moderate Reason," "Major Reason," or "I prefer not to answer.")

- Technology plays an important role in solving society's problems.
- Engineers make more money than most other professionals.
- My parent(s) would disapprove if I chose a major other than engineering.
- Engineers have contributed greatly to fixing problems in the world.
- Engineers are well paid.
- My parent(s) want me to be an engineer.
- An engineering degree will guarantee me a job when I graduate.
- A faculty member, advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering.
- A non-university affiliated mentor has encouraged and/or inspired me to study engineering.
- A mentor has introduced me to people and opportunities in engineering.
- I feel good when I am doing engineering.
- I like to build stuff.
- Engineering skills can be used for the good of society.
- I think engineering is interesting.
- I like to figure out how things work.

7. Please indicate how strongly you disagree or agree with each of the statements below:

(For each of the items below, survey participants selected one of: “Strongly Disagree,” “Disagree,” “Agree,” “Strongly Agree,” or “I prefer not to answer”

- Creative thinking is one of my strengths.
- I am skilled at solving problems that can have multiple solutions.
- A mentor has supported my decision to major in engineering.

8. Rate yourself on each of the following traits as compared to your classmates. We want the most accurate estimate of how you see yourself.

(For each of the items below, survey participants selected one of: “Lowest 10%,” “Below Average,” “Average,” “Above Average,” “Highest 10%,” or “I prefer not to answer.”)

- Self-confidence (social)
- Leadership ability
- Public speaking ability
- Math ability
- Science ability
- Communication skills
- Ability to apply math and science principles in solving real world problems.
- Business ability
- Ability to perform in teams
- Critical thinking skills.

9. How important do you think each of the following skills and abilities is to becoming a successful engineer?
   (For each of the items below, survey participants selected one of: “Not Important,” “Somewhat Important,” “Very Important,” “Crucial,” or “I prefer not to answer.”)
   - Self-confidence (social)
   - Leadership ability
   - Public speaking ability
   - Math ability
   - Science ability
   - Communication skills
   - Ability to apply math and science principles in solving real world problems.
   - Business ability
   - Ability to perform in teams
   - Critical thinking skills.

10. Rate your degree of confidence (i.e. belief in your current ability) to perform the following tasks by selecting a number from 0 to 100, where 0 = cannot do at all; 50 = moderately can

do; 100 = highly certain can do. (Survey participants were given a choice to select numbers from 0 to 100 in increments of 10).

- Conduct engineering design
- Identify a design need
- Research a design need
- Develop design solutions
- Select the best possible design
- Construct a prototype
- Evaluate and test a design
- Communicate a design
- Redesign
- Work as part of a team

11. Rate how motivated you would be to perform the following tasks by selecting a number from 0 to 100, where 0 = not motivated at all; 50 = moderately motivated; 100 = highly motvated. (Survey participants were given a choice to select numbers from 0 to 100 in increments of 10).
    - Conduct engineering design
    - Identify a design need
    - Research a design need
    - Develop design solutions
    - Select the best possible design
    - Construct a prototype
    - Evaluate and test a design
    - Communicate a design
    - Redesign
    - Work as part of a team

12. Rate how successful you would be in performing the following tasks by selecting a number from 0 to 100, where 0 = not successful at all; 50 = moderately successful; 100 = highly successful. (Survey participants were given a choice to select numbers from 0 to 100 in increments of 10).
    - Conduct engineering design
    - Identify a design need
    - Research a design need
    - Develop design solutions
    - Select the best possible design
    - Construct a prototype
    - Evaluate and test a design

- Communicate a design
- Redesign
- Work as part of a team

13. Rate your degree of anxiety (how apprehensive you would be) in performing the following tasks by selecting a number from 0 to 100, where 0 = no anxiety at all; 50 = moderately anxious; 100 = highly anxious. (Survey participants were given a choice to select numbers from 0 to 100 in increments of 10).
    - Conduct engineering design
    - Identify a design need
    - Research a design need
    - Develop design solutions
    - Select the best possible design
    - Construct a prototype
    - Evaluate and test a design
    - Communicate a design
    - Redesign
    - Work as part of a team