Differences in First Year Gender Engagement Through Cross-Disciplinary Design Projects

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Structured Abstract

BACKGROUND
Leading engineering companies across a variety of industries, such as Intel and Imperial Oil, are launching education initiatives to encourage well-rounded, diverse and creative future engineers (Intel Corporation, 2012) (University of Calgary, 2013). Employers are looking for graduates capable of critical, creative thinking, multi-disciplinary teamwork, and cross-disciplinary innovation, as well as demonstration of engineering graduate attributes. This work examines the use of student interests to create cross-disciplinary first year design projects to encourage engagement, creativity and diversity.

PURPOSE
The long-term hypothesized impact of this work is to increase the level of engagement among first year engineering students, consequently improving retention and enhancing the comprehension of engineering design practices and attributes. Spanning multiple years, this study includes the development of real world design problems with connections to subject areas that are of interest to incoming students, including political/societal issues, artistic design concerns, and creative innovations. Preliminary analysis and implementation of these cross-disciplinary projects will be discussed, as well as considerations taken for the 2014 introductory design course projects.

DESIGN/METHOD
The outcomes for this study have been tested using both qualitative and quantitative research methods. Student interests and hobbies were measured through an anonymous survey distributed in 2012 and 2013. These surveys also examined the perceptions that students hold around engineering, and their opinions on gender diversity and gender capabilities within the field. In 2013, students were also asked to rate their first year design course projects and identify some of the positive and negative experiences found throughout the laboratory sessions. These projects were developed by a team of interdisciplinary researchers and incorporated engineering design techniques and graduate attributes with fine arts, societal issues, mathematics, physics, research, technology and writing.

RESULTS
To date, this study has shown trends regarding student interest in first year design projects. The quantitative data showed that 72% of female students care more about a project when it has real world applications, and their most preferred project in 2013 related to a local disaster issue. On the other hand, 72% of male students stated that they care more about a project when it challenges them. Their favourite project in the course was the least constrained design challenge with a single focused task. Male students were also significantly more likely to care about a project when it is very technical. Regardless of gender, 97% of all the students agreed or strongly agreed that they care more about a project when it relates to their hobbies and interests. Student perspectives and feedback will be examined again for the first year design course being run in September 2014.

CONCLUSIONS
In summary, this research examines how gender diversity affects student engagement in the design process. The projects developed as part of this work also encouraged critical thinking, teamwork, and creativity, which are skills required in the engineering workplace. From the results shown, applying cross-disciplinary methods and integrating societal issues into introductory engineering design can help to create engaging engineering projects that appeal to both male and female students.

KEYWORDS
First year design, cross-disciplinary projects, diversity.

Introduction

As technologies and innovations continue to grow, leaders in engineering industries such as Intel, Google and Imperial Oil are investing their resources into the development of creative, future engineers (Intel Corporation, 2012) (University of Calgary, 2013). Researchers have also seen the need for educating creative engineers, and many support tools, assessment rubrics, and developing design processes for the classroom (Charyton, Jagacinski, Merrill, Clifton, & DeDios, 2011) (Shneidermann, 2007) (Simpson, Barton, & Celento, 2008).

In many institutions, students are first introduced to design and engineering creativity in a first-year design course. This early course not only provides application opportunities for theoretical and technical work, but it also lays the foundation for developing engineering graduate attributes, such as those defined by the Canadian Engineering Accreditation Board (Engineers Canada, 2012).

The work in this study examines first-year engineering student perceptions and proposes related cross-disciplinary design projects intended to encourage student engagement, interest, and creativity. This work also makes observations regarding the types of projects more likely to engage female students, male students, and both genders together.

Methodology

The methodology for this work has been split into two rotating phases that have alternated across multiple years. One phase examines quantitative survey results regarding first-year students' interests and perceptions around engineering, while the other phase applies that information to the development of design projects suitable for an introductory engineering design course.

Quantitative Survey on Engineering Perceptions

The first phase is a survey that is offered to all first-year engineering students enrolled at the Schulich School of Engineering. Students were asked to complete a survey about their interests, perceptions around engineering, and their influences for choosing engineering as a field of study.

The first version of the survey was distributed in 2012 to all first-year students. The survey link was distributed through email, and filled out anonymously using an online survey program. Out of approximately 700 students, 144 students participated in the study, with 37% of the participants identifying as female, and 63% as male. This gender division was slightly higher than the faculty average of 24%.

The 2013 version of the survey was primarily the same as the previous version, but was also expanded to include quantitative and qualitative questions about course project feedback. The participants were split 45% female and 55% male, which was again higher than the entrance ratio of 24% female students.

First-Year Design Course

The second phase applies the information learned in the survey to the development of engaging projects for the mandatory first-year design course.

All incoming first-year students at the Schulich School of Engineering take a full year of common engineering courses, including a course on design and communication called ENGG 200. This introductory design course introduces basic design principles and processes, teamwork, creative thinking while solving team-based exploratory problems.

While the projects vary each year, a typical offering of the course includes one or two one-week projects, and two or three multi-week projects. Students work in the same teams of

four throughout the entire semester, and are led by the same teaching assistant. Laboratory projects are accompanied by twice weekly lectures on design theory, ethics, and communications.

2013 Project Design

Following the 2012 survey, the initial results were considered in the design of the ENGG 200 projects for 2013.

The 2013 instructional team developed the Fall 2013 projects to follow the theme of "No Impact Man", based on the corresponding book that was assigned through the general university's common reading program. This theme focused on reducing individual environmental impact through recycling, reusing, and sustainability.

An interdisciplinary team of engineering researchers and professors designed four laboratory projects by combining engineering design and arts concepts into problem-solving exercises. Each project introduced and expanded aspects of the engineering design process and techniques for developing a complete project and/or design.

Student engagement and diversity were considered through the integration of cross-disciplinary principles. Technical engineering content was combined with fine arts, societal issues, mathematics, physics, research, technology and writing to encourage creativity, connections, and interest from a diverse range of students with varied backgrounds, ethnicities, and gender.

Project 1 – No Impact Orchestra

The first, introductory project was a three-hour design task where student teams of four were asked to design and construct two musical instruments capable of producing five identifiable and repeatable frequencies. Teams were only allowed to use materials that were eligible for the city's blue bin recycling program, including paper, cardboard, plastic, cartons, etc. The technical concepts explored in this task required a review of high school physics, including frequency measurements and calculations, and involved the use of basic measurement tools. Upon completing their instruments, teams had to demonstrate both to the teaching assistants and to their fellow classmates. At the end of the lab, all teams played their instruments together as the Schulich No Impact Orchestra.

This project was developed in conjunction with Beakerhead, a new city-wide festival for promoting the connections between engineering, science, and the arts. Students were invited to demonstrate their prototypes at an evening community event, and were also encouraged to submit their own music videos. Despite this being their first introduction to postsecondary teamwork, nearly all the teams were completely successful in achieving the design goals.

Project 2 – Target on Budget

During the second laboratory sessions, teams were asked to design and build a structure capable of delivering a hockey ball from a pre-specified start height to a target on the floor. The structures were required to cross a certain horizontal and vertical distance, and were also required to have a completely horizontal bridge span of a certain length. Teams were again limited to recyclable materials, and were provided with a finite amount of "money" to spend on these materials. Along with budgetary concepts, teams again developed their critical thinking, time management, and teamwork skills. The students were also given the opportunity to learn about basic structural techniques, which were required for the next project. Overall, most teams were successful in completing the design task, with varying degrees of accuracy in the final landing location within a gradated target.

Project 3 – No Impact Bridge

The third project of the semester was a multi-week assignment that involved design decision-making, research, prototyping, oral presentations, and finally testing. Recycled materials

were again used to develop a bridge, but this project required more research into an actual disaster. The local urban and rural areas were devastated by excessive flooding in the spring of 2013, with some areas of the nearby backcountry being washed away completely. Students were tasked with proposing a sustainable bridge design that could be used to rebuild the backcountry trails. The design had to be able to be assembled in remote areas accessible only by helicopter, requiring students to consider the weight, dimensions, and strength of their materials. Each team constructed a prototype that was subjected to horizontal and vertical load testing, using scaled down measurements of real environmental stressors such as water and wind. Students were graded on aspects such as their choice of materials, their methods of adhesion, and their ability to bear a load. Teams were also required to demonstrate skills such as researching, sketching, and prototyping. This project was developed in conjunction with Parks Canada and offered the students a chance to have their designs developed further as viable bridge replacement options.

Project 4 – Corner to Corner

The fourth and final project in the course was a multi-week open-ended design challenge. Teams were tasked with creating a vehicle capable of moving from one corner of a table to the diagonal corner, while also navigating a large obstacle placed across the centre of the platform. In this case, students were allowed to expand beyond recyclable materials, but could only spend up to $20. Each group was also provided with a motor, some wheels, and a set of batteries, all for optional use. With few restrictions defining the design task, vehicles were free to manoeuver through the narrow gap around the obstacle, climb over, flip, move, etc. past the obstacle. To achieve a passing grade, teams were required to pass the obstacle, and their final score was then based on the vehicle's final stopping distance from the target end corner.

Results

Quantitative Results on Engineering Perceptions

Overall, the survey data trends seen between 2012 and 2013 students were fairly consistent, with some variation most likely due to the smaller sample size in 2013.

Students were asked to identify their preferred extracurricular hobbies and interests, with the intention of incorporating student passions into future design projects. Female students rated sports/athletics as their top hobby, while male students rate computer games most highly. Both genders also gave high precedence to social media and chess/puzzles/board games, and neither showed a preference for traditional science or mathematics related hobbies.

On average, only 61% of students agreed or strongly agreed that they know what an engineer does, despite choosing the field as their future career path. However, 86% of students did recognize that engineers have to be creative. Over 85% of students also agreed that engineers design cool things, that they help society, and that they are respected, showing a generally positive perception of engineering in Figure 1.

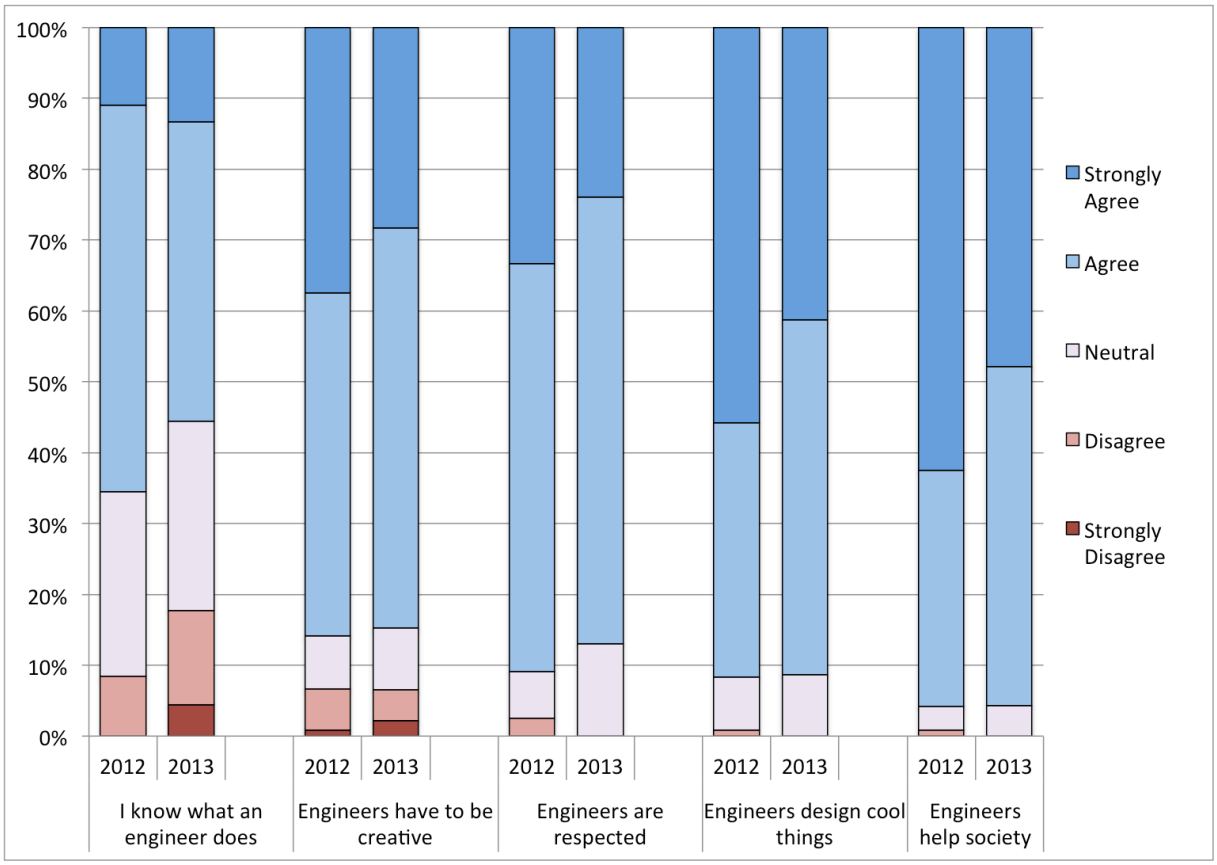

Figure 1: First-year students in 2012 and 2013 reflected positively on their perceptions of engineering as a career.

Students were more split when it came to gender issues within engineering. While 80% disagreed or strongly disagreed that the best engineers are men, only 70% disagreed that engineering skills come more naturally to men. Also, only 59% of students disagreed that men are less creative than women, even among the male students. This percentage could possibly show a bias towards the way students think about creativity, believing it to be an artistic "female" trait rather than a critical thinking or innovative skill. These results are shown in Figure 2.

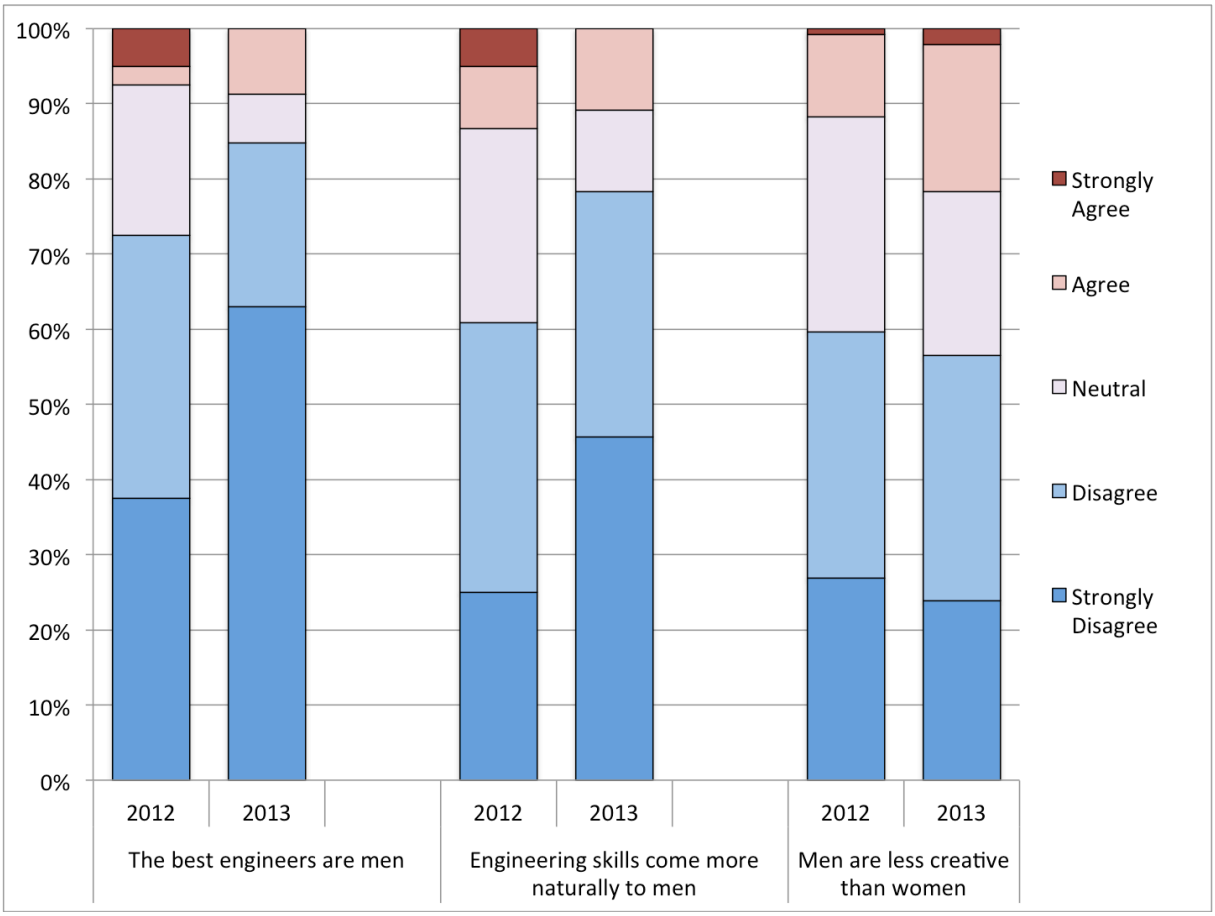

Figure 2: First-year students in 2012 and 2013 reflected some gender biases in their responses to related engineering statements.

Design Project Feedback

The 2013 survey was expanded to request project feedback from the students. Each student was asked to rank the four projects from their least favourite (4) to their favourite project (1). Female students were split among their ranking of the bottom three projects, but 47% of females rated Project #3 (bridge) as their favourite project. The male students, on the other hand, preferred Project #4 (vehicle/obstacle), with 59% of males ranking it as their favourite project. Half of the male students also ranked Project #1 (musical instruments) as their least favourite project. These results are reflected in Figure 3.

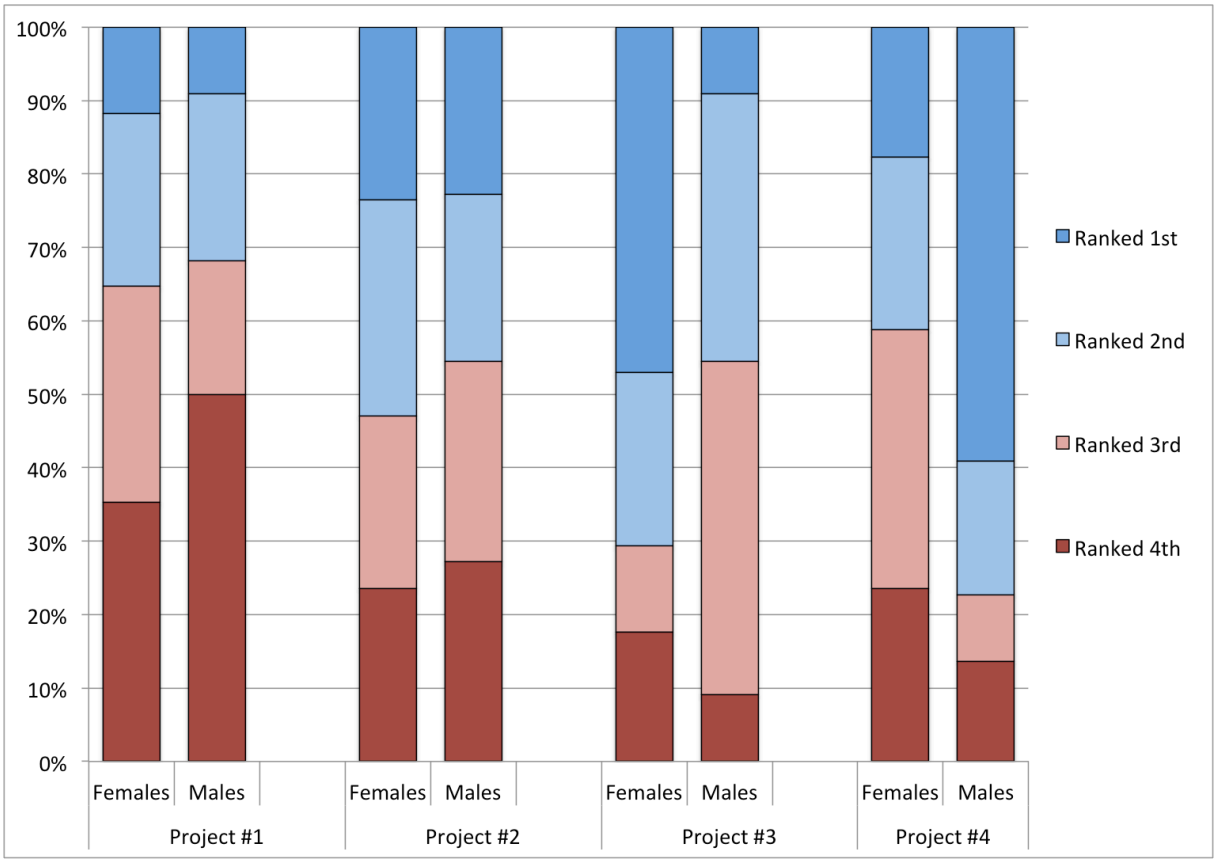

Figure 3: Female students rated the project with the most real world applications as their favourite, while male students preferred the project with the most technical challenge.

Student Engagement

The students were also asked how much they agreed with statements regarding their interest in general projects, with the results being shown in Figure 4. Nearly all of the students agreed or strongly agreed that they care more about a project when it relates to their hobbies/interests. Females, on the other hand, care more about a project when it has real world applications, with 72% agreeing or strongly agreeing compared to 62% of male students. This also reinforces the top female ranked project, the flooding/bridge project, which had the most connections to a real societal disaster requiring engineering assistance.

In contrast, 72% of males agreed or strongly agreed that they care more about a project when it challenges them, whereas only 61% of females felt the same. Also, 90% of male students are more interested in technical projects, compared to only 39% of female students. Again, this reflects the top male ranked project, the vehicle/obstacle project, which was the most open-ended and difficult design challenge of the four projects.

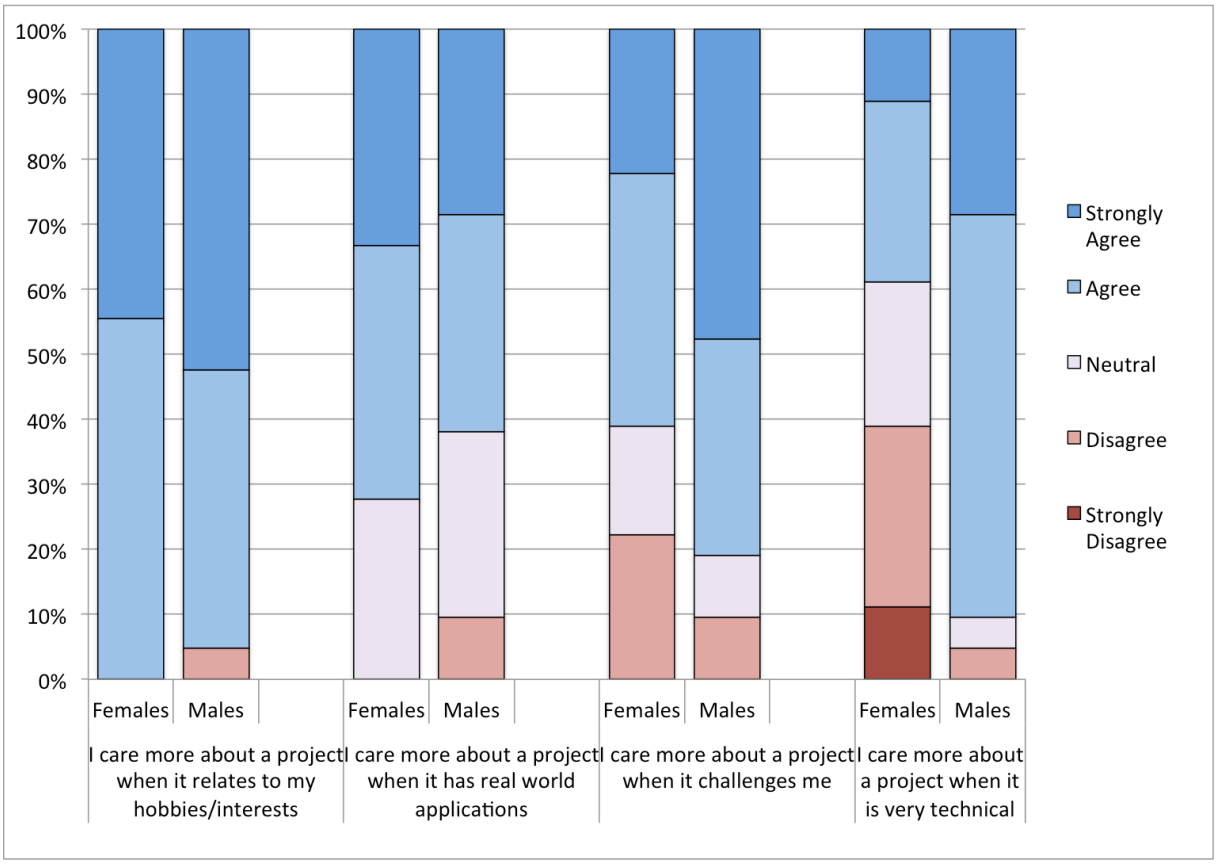

Figure 4: Female students are more likely to be interested in a project that has real world applications, while male students care more about a project when it is very technical.

Additional Feedback

In addition to quantitative feedback, students were also asked to suggest some qualitative improvements or extensions to the four projects. In general, students were frustrated by the recyclable materials constraint in projects 1-3, and were interested in repeating those design challenges with unlimited materials. Time frame also played an important role, with many students preferring the design process outlined in the multi-week projects, as opposed to the rapid design required in the three-hour challenges. Team dynamics also affected how the students responded to a project, as their experience was sometimes helped or hindered by the relationships within the team.

Study Continuation

Project Design for 2014

Now that two years of survey data has been collected, the 2014 instructional team is continuing to integrate the study results into their project design ideas. The 2014 ENGG 200 projects will again follow a theme, this time relating to space exploration and Mars missions. A related book study has also been integrated into the communications aspect of the course to integrate creative English concepts with engineering problem-solving. Students will also be offered a choice between two projects during the first multi-week assignment, giving them the option between a creative game development project and an open-ended biomimicry research project. The 2014 projects reflect the students' interests in societal impact, computer games, socialization, and challenging problem-solving, and will give students a chance to develop their creativity in an engineering context.

Other trends from the 2013 data will continue to be investigated in 2014. For instance, 44% of the 2013 students stated that they were much or very much influenced to choose engineering because they wanted a creative career. These students were also more likely to care about a project if it relates to their interests, has real world applications, and is challenging, regardless of their gender. These students also showed a preference for hands-on design and a career that will positively impact society. All of these attributes are considered desirable in an engineering student or future engineer, and the 2014 version of the survey will continue to investigate students who show an aptitude or interest in creativity within engineering.

Conclusions

The data in this work shows that the students were engaged in projects differently depending on their gender. This information can be used to adapt engineering design projects to appeal to a wider range of students, which may improve post-secondary recruitment or retainment. While male students were more evenly interested across all types of projects, female students showed significant preference for real world applications compared to purely technical projects. Modern engineering schools must consider how to design curriculum and projects that appeal to all students, rather than the traditional male demographic.

In conclusion, this study investigates the perceptions held towards engineering by first-year students, and proposes cross-disciplinary design projects developed using the students' perceptions and interests to encourage engagement. As engineering classes continue to grow more diverse, curriculum designers must consider content that appeals to the creativity of various genders, ethnicities, and backgrounds. The results in this work showed that students were more likely to be interested and therefore more engaged in a project when it reflected their own values.

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