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Assessing the Impact of Incorporating the NAE Grand Challenges for Engineering as a Multidisciplinary Hands-On Design Project into the Introduction to Engineering Course

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Abstract

This evidence-based practice paper will discuss the effect of incorporating a National Academy of Engineering (NAE) Grand Challenges[1] themed project into the Introduction to Engineering course on first year students' motivation, value, and perception of engineering. At Arizona State University, the NAE Grand Challenges for Engineering have been incorporated into the 2-credit Introduction to Engineering course as the subject of a multidisciplinary hands-on team design project. The three Grand Challenges that were selected for inclusion in this project were make solar energy economical, provide access to clean water, and advance personalized learning; a real world problem was formulated for each of these three areas. In the design project, student teams work through the engineering design process to design a solution to the problem, build a functional prototype of their solution, and test their prototype to demonstrate the effectiveness of their solution. A custom survey instrument based on APPLES (academic pathways of people learning engineering)[2], the engineering motivation survey[3], and the model of situational interest in classroom setting[4] was administered to students at the start and end of the class to assess the impact of the Grand Challenges themed design project. Results showed that using the NAE Grand Challenges to provide real world context for the design project positively changed students' perception of engineers' roles and the impact of engineering solutions. Qualitative results indicate that as a result of the project, more students recognized that engineers' roles include promoting 'social good' in addition to designing and creating. Although no significant impact on students' motivation was observed, the project did have a positive impact on students' situational interest.

Introduction

This work describes the use of real world problems related to the NAE Grand Challenges for Engineering as the subject of a hands-on multidisciplinary team design project in an Introduction to Engineering course. The three Grand Challenges that were selected for inclusion in this project were make solar energy economical, provide access to clean water, and advance personalized learning. Engineering education literature has shown that exposure to real world problems and applications in society increases students' interest and learning[5]. The NAE Grand Challenges provide a diverse set of real world engineering problems that can be used in courses to provide students with these contextual learning opportunities. Several institutions have incorporated the NAE Grand Challenges into courses throughout the engineering curriculum in order to provide context for the technical content[5-8] or to introduce the engineering profession and disciplines[9-11]. Many institutions have also established co-curricular programs such as the

Grand Challenge Scholars Program which aims to educate the next generation of engineers to be prepared for these challenges[12]. However, only a selected group of students are enrolled in those programs and many engineering students are not provided with opportunities to learn about the NAE Grand Challenges for Engineering. The research thus far has shown that incorporating the NAE Grand Challenges into engineering curriculum has increased course effectiveness and student motivation[6-10], has fostered student critical thinking abilities, and has changed students' awareness of engineer's role in the global community[13]. This work aims to observe similar effects due to the incorporation of NAE Grand Challenges into the Introduction to Engineering team design project.

This work focuses on using the NAE Grand Challenges to provide first year students with design challenges that help them to see the role engineers play in society. A few other institutions have used the NAE Grand Challenges in their first year engineering courses to provide real world examples of multidisciplinary engineering, introduce the engineering profession, and provide context and relevance for engineering[9-11,13-16]. Corneal et al. and Azarin et al., for example, both asked students to research multidisciplinary engineering work related to the Grand Challenges in order to learn more about the engineering profession and disciplines[9,11]. Argrow et al. describes integrating Grand Challenges into a course with similar aims (engineering profession, disciplines, academic success), but asked students to complete the first steps of the design process in the context of the Grand Challenges. Specifically, they asked students to identify specific problems in the Grand Challenge areas and develop design requirements; in this case the students were not asked to develop solutions[10]. In other first year programs, the Grand Challenges have been used to provide relevant context for hands-on engineering design and analysis activities[14-16], however, in those activities students are never asked to actually design, build, and test solutions to real world problems. In this work, real world problems related to the Grand Challenges are used as the subject of a 9 week (or longer) hands-on design project. Student teams are provided with real world problem scenarios and they work through the engineering design process to develop requirements, design a solution to the problem, build a functional prototype of their solution, and test their prototype to demonstrate the effectiveness of their solution.

The impact of this novel way of incorporating the NAE Grand Challenges for Engineering in the first-year curriculum on student motivation, value, and their perception of engineering and engineers' role in the society was assessed. A custom survey instrument based on APPLES (academic pathways of people learning engineering)[2], the engineering motivation survey[3], and the model of situational interest in classroom setting[4] was administered to students enrolled in 5 sections of this course taught in the Fall 2015 semester. The survey was administered once at the beginning of the semester and once at the end of the semester after students have completed the design project.

In this paper, details of the hands-on design project which is based on the NAE Grand Challenges will be presented. Survey results will be analyzed both quantitatively and qualitatively and will be compared. Observations from the survey results will be discussed and recommendations for future work will be given.

Implementation of the NAE Grand Challenges Team Design Project

The 2-credit Introduction to Engineering course at Arizona State University has been designed to utilize best practices found in the first year engineering curriculum including project-based learning, team based hands-on experiences, and incorporation of real-world multidisciplinary engineering problems. It focuses on the engineering design process, teamwork, communication, and other skills that are important for engineers. It also introduces students to tools that will be useful in their future curriculum and careers. This multidisciplinary course is offered to mechanical, aerospace, chemical, and electrical engineering majors and it meets for one 50-minute lecture and one 3-hour lab each week during a 15-week semester. Students in the course are given the opportunity to apply the engineering design process, as well as practice and/or learn other important engineering skills by working on a hands-on team-based design project during the labs in a makerspace.

In the past, various design projects have been implemented in this course including a solar-powered vehicle design project, a renewable energy power plant design project, an autonomous waste sorter design project, and others. However, many of them did not have close real world connections and even though students were able to practice applying the engineering design process and various skills, they found it difficult to see the impact of their solutions in the real world. Another critique that was often observed in course evaluations was that students were not given the freedom to choose which project they worked on. A new hands-on design project was needed to address these issues, and the NAE Grand Challenges were chosen as the subject. The NAE Grand Challenges are the most important and urgent issues that engineers should focus on and engineering students should be prepared to tackle these challenges. More importantly, engineering students should be exposed to these challenges early in their curriculum so that they could better understand engineers' roles in the society and how engineers can impact the world. The NAE Grand Challenges provide a great background for a hands-on design project for the freshman Introduction to Engineering course as they provide a diverse set of real world problems that suit students with a variety of interests.

All 14 NAE Grand Challenges were carefully reviewed and the following 3 challenges were selected to be incorporated: provide access to clean water; make solar energy economical; advance personalized learning. These specific challenges were chosen based on relevance to the students' engineering disciplines (mechanical, aerospace, chemical, electrical engineers) and the feasibility of a freshman level single-semester hands-on design project. For each challenge, a real world scenario was formulated with specific requirements and student teams were asked to choose one of these three design problems to work on. For the challenge “provide access to clean water”, students were tasked to design an inexpensive, commercializable system that addresses the issues of transportation and purification of water from an open pond in the village Mawanga of Uganda. For prototype testing, a contaminated water sample was created based on a carefully selected ‘recipe’ to simulate the pond water. For the “make solar energy economical” challenge, students were asked to design, build, and test a solar power plant at relatively low cost that could provide consistent electrical power throughout the day (despite the changing position of the sun) for villagers living next to the Taklamakan desert in China. A project testing setup that simulated the sun’s movement over time on a small scale (shown in Figure 1) was created to test the effectiveness of the functional prototypes.

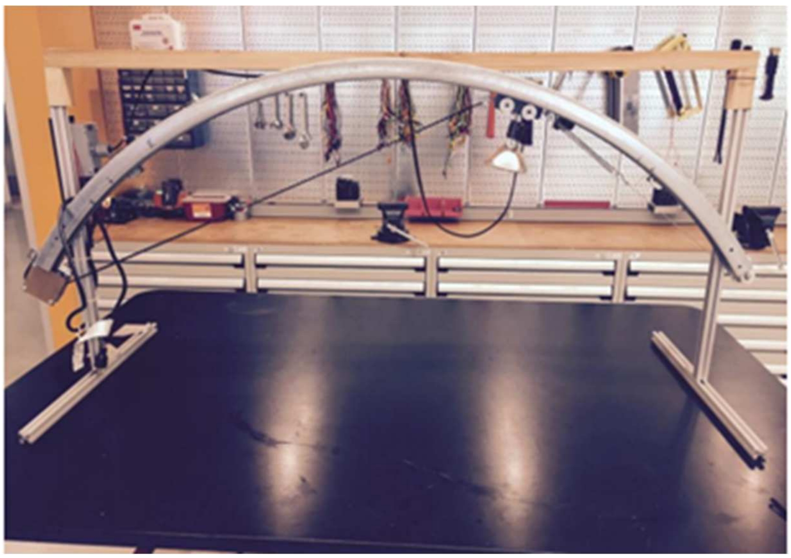

Figure 1. Project testing setup

For the two challenges just described, villages located in rural areas around the world were used to provide students with the opportunity to consider the real needs of a community that they are not familiar with and to help them better understand how engineering solutions can be affected by realistic constraints such as cost and resources. Finally, for “advance personalized learning”, students were tasked to create fun and interactive educational exhibits or toys for a community science center to teach a scientific principle of their choice to people with different learning styles. More details of all three project scenarios can be found in Appendix A. In addition to the specific requirements provided for each design problem, all designs also had to be creative, aesthetically pleasing, well crafted, and cost as little as possible.

Students were assigned to teams of 3 or 4 at the beginning of the semester based on a set of criteria (e.g., gender, race, software skills, hands on skills, English skills, commitment level, leadership preference, etc.), using CATME SMARTER teamwork (www.catme.org). In each section of this course for this study, there were approximately 40 students divided into 10 teams. When the design project was introduced to students, all teams had the freedom to select one of the three problems to work on. Out of the three problems, the first and the second (i.e., "provide access to clean water" and "make solar energy more economical") were equally popular among all the teams and very few teams selected to work on the third problem ("advance personalized learning"). To assist student teams in working through the engineering design process, the following intermediate project deliverables were used: problem definition; project schedule; project proposal (oral presentation and written document); progress report memo. Final project deliverables included a functional prototype, a final oral presentation, and a final written report. Various techniques and tools were introduced to students before or during the design project, including ideation techniques, decision matrix, Gantt charts, mathematical modelling, visual models, MATLAB, etc., and students were given opportunities to go through all the steps in the engineering design process. More specifically, one lab period was provided for students to fully define the problem; one for ideation, one for experimenting, modelling and analysis; one for decision making and finalizing details of proposed design; one for proposal presentations; and four or five for prototype construction and testing. During each of the lab sessions, three teaching staff members (the instructor, a graduate teaching assistant, and an undergraduate teaching assistant), were present to help the teams with the project (teaching staff to student ratio: 3 to 40). Overall, most of the teams had very successful designs; 79% of the teams that worked on each problem (problem 1 and problem 2) had successful prototypes. All of those that worked on the third problem were able to successfully solve the problem.

Before this design project was introduced to students, a jigsaw activity was also used to introduce students to the 14 NAE Grand Challenges. For the jigsaw activity, each student team performed research on one of the 14 Grand Challenges and presented their findings to the entire class. Specifically, students were asked to research and report on the key challenges in the Grand Challenge area and to provide examples of what engineers can do to help solve the challenges.

Assessment Method

To assess the impact of the incorporation of the NAE Grand Challenges for Engineering as a hands-on design project on students' motivation, value, and their perception of engineering and engineers' role in the society, a survey instrument adapted from APPLES (academic pathways of people learning engineering) survey[2], the engineering motivation survey[3], and the model of situational interest in classroom setting[4] was utilized. The questions adapted from the APPLES survey were used to gain insight on students' motivation to study engineering; those from the engineering motivation survey measure attainment value; and the model of situational interest in classroom setting questions assess learning applied to real life. All of these questions are based on a Likert scale of 1-5, with 1 being either not a reason or strongly disagree and 5 being a major reason or strongly agree. In addition, the following two open-ended questions have been included in the survey: "Can you give some examples of what kind of roles engineers can play in the society?" and "As a result of working on the Grand Challenges Design Project and learning about the Grand Challenges for Engineering, discuss and share an important example of learning, growth, and/or development that has occurred". The complete survey can be found in Appendix B. The survey instrument was administered online via Google Forms twice to 5 sections of this course taught in fall 2015 by the authors: once at the beginning of the semester (questions 10 and 11 were excluded from the pre-survey) and once at the end of the semester after students have completed the hands-on design project. In three of the sections, the survey was administered during the lab periods and students were given about 10 min each time to complete it. In the other two sections, the survey link was posted to the Blackboard course site each time and students were given a few days to complete the survey and reminded to complete it via email. In order to link pre- and post-survey responses, an anonymous username that is unique to each student was collected each time (first two letters of their middle name, first two letters of their mother's maiden name, and two numbers of the day they were born).

Results and Discussion

A total of 40 responses (~24% response rate) were received for the pre-survey and 68 (~ 41% response rate) were collected for the post-survey. Out of these participants, 12 completed both the pre- and post-surveys. The low participation rate was probably due to the fact that the surveys were completely voluntary and no incentives were provided. Thus, students may have lacked the motivation to complete them. Figures 2 and 3 below show the majors of the participants of both the pre- and post- surveys.

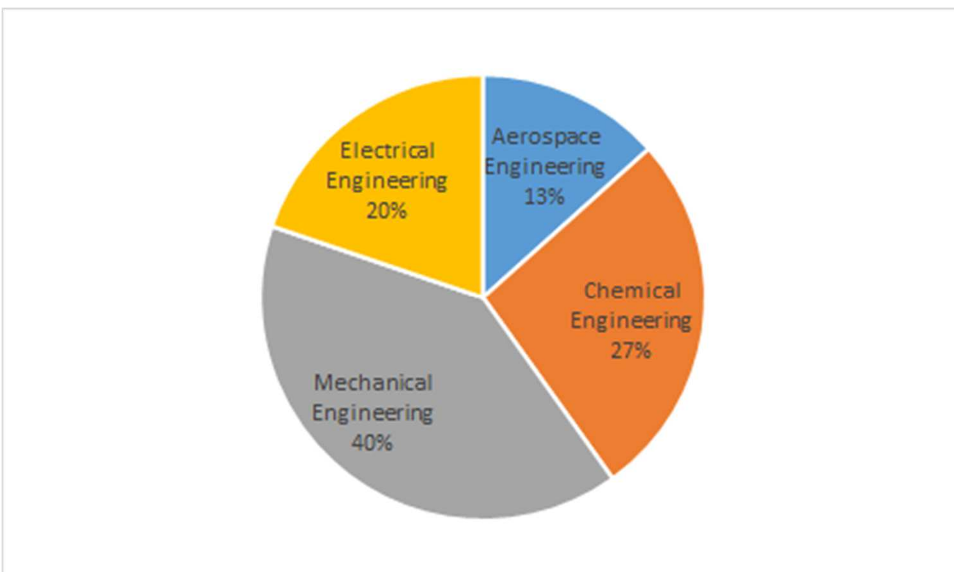

Figure 2. Pre-survey participant majors

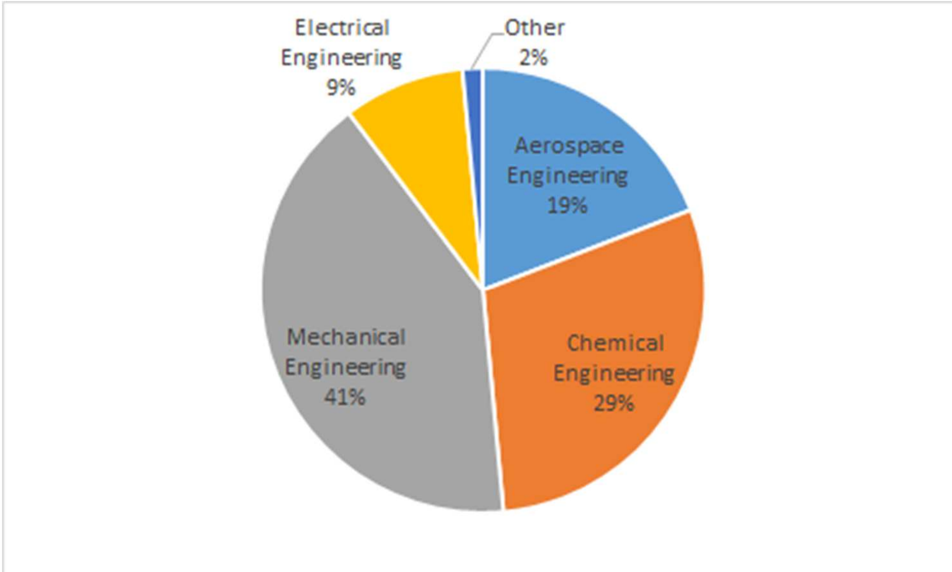

Figure 3. Post-survey participant majors

For all of the questions based on a Likert scale, mean scores were calculated for all pre- and post-test responses and an independent t-test was used to check for statistical significance of any differences between the means. The 12 linked pre-and post-survey responses were analyzed using a Wilcoxon signed-ranks test for paired samples. Unfortunately, the results may not be representative of the population due to the small sample size and unequal sample sizes between pre- and post-tests.

Items in question 5 of the survey have been grouped into 6 categories according to the APPLES survey[2]: extrinsic factors such as financial and social good, intrinsic factors including psychological and behavioral, and relationship factors, for example, parental and mentor influence. Figure 4 shows the comparison between the pre-and post-responses for survey question 5(the 12-linked response results are very similar and thus are not shown here). Similar mean scores were found between the pre- and post-responses for the 6 motivational factor categories and no changes were statistically significant ($p>0.05$) for the overall sample or for the linked responses. Items from question 6 that measure attainment value, which is considered one of the constructs of expectancy of success, part of the expectancy-value theory within the motivation theories[3], are shown in Table 1. Again, the differences between results were not found to be significantly different ($p>0.05$). Similar mean scores were also, again, found to be similar for the 12 linked responses and differences in results were not found to be significantly different ($p>0.05$).

The trends in the results described above were found to be similar to the results from the APPLES survey[2] when the motivation was compared between seniors and first year engineering students. The profiles of motivation between the two groups were found to be very similar and according to the APPLES survey[2], students' motivation to study engineering may take shape early in their educational experiences and college experiences may just reinforce the initial motivation. Such stability in motivation was also found in other studies[17], including Huettel et al. who also found no significant effects on first year students' motivation as a result of incorporating Grand Challenges into the curriculum[7]. Thus, it was not surprising that the NAE Grand Challenges design project did not significantly change students' motivation to study engineering.

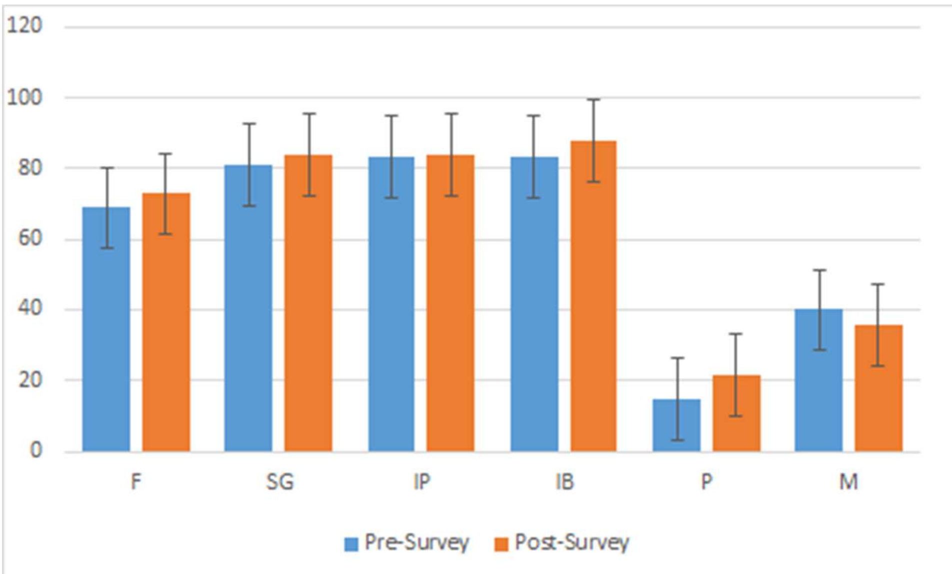

Figure 4. APPLES motivation pre-and post-survey results (F=Financial; SG=Social Good; IP=Intrinsic (Psychological); IB=Intrinsic (Behavioral); P=Parental Influence; M=Mentor Influence)

Table 1. Comparison of pre and post survey results for questions related to Attainment Value

	Pre-survey		Post-survey		
	Mean	STD	Mean	STD	P value
The amount of effort it will take to get my engineering degree is worthwhile to me.	4.44	0.79	4.30	0.71	0.3238
Being good at solving engineering-related problems is important to me.	4.36	0.84	4.33	0.70	0.7813
Getting an engineering degree is essential to being the person that I want to become.	3.85	0.99	3.78	0.91	0.6211
I am becoming an engineer by working towards my degree.	4.18	0.88	4.07	0.75	0.4261

I want to become an engineer.	4.54	0.60	4.33	0.76	0.1251
I am an engineer.	3.95	0.92	3.76	1.03	0.2828
Attainment Value (Total)	24.80	5.16	24.48	3.47	0.6926

Results of the other items in survey question 6 are presented in Figures 5-6. A significant increase ($p<0.05$) was seen for the survey question "I see how I can apply what we have learned in this course to real life," which measures situational interest, from the pre- to the post-survey when the 12 linked responses were analyzed (shown in Figure 6). According to Linnenbrink-Garcia et al., maintained situational interest can be promoted by the learning contexts when individuals feel empowered by the knowledge presented to them in the situation[4]. Thus, the result indicates that the real world learning context that was given to students in this course has had a very positive impact on students' maintained situational interest, which can grow into personal interest. An increase was also seen for linked responses for the survey question "I am confident that I could successfully design a solution for a community". Although this increase was not significant, it was still an interesting result as it indicates that some individual students became more confident in their engineering design skills as a result of participation in the team design project.

Figure 5. Pre-and post-survey results (survey question 6)

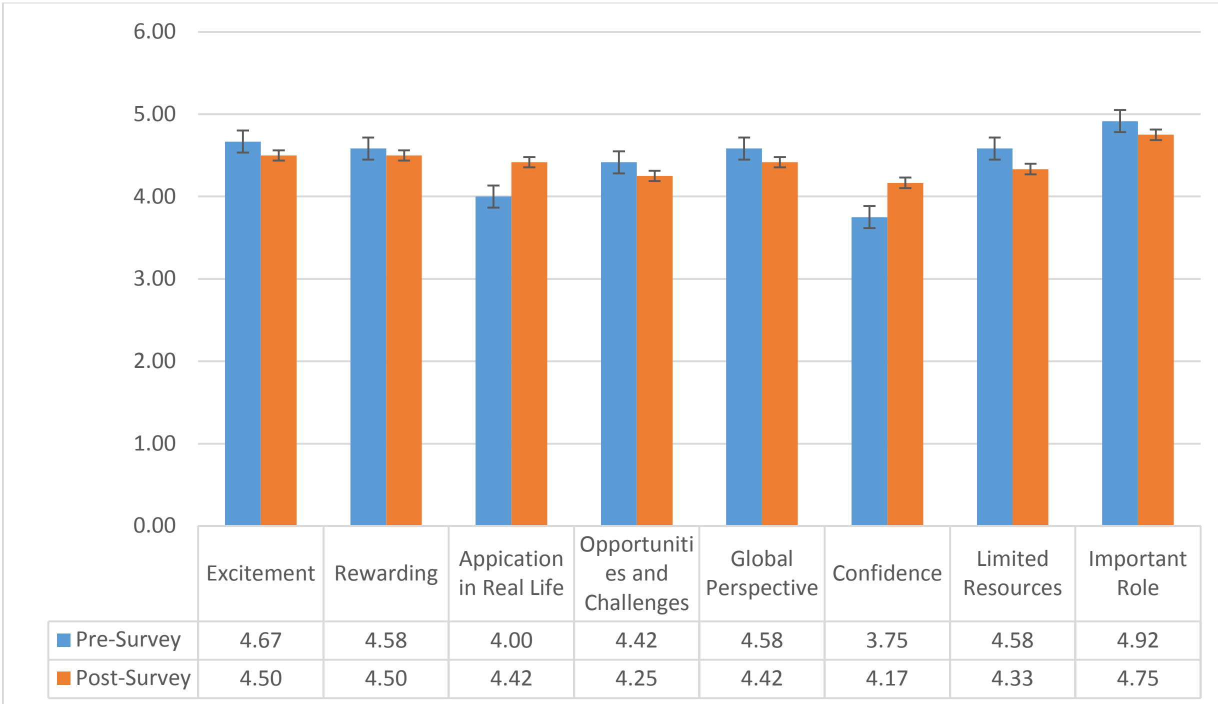

Figure 6. Pre-and post-survey results (survey question 6) for 12 linked responses

Participants were also prompted to give examples of roles that engineers play in the society after responding to the last item of question 6 ("engineers play an important role in society"). All responses to this open-ended question have been coded and grouped into different themes by one of the authors and the second author validated the coding. Results of this can be found below in Tables 2 and 3. For the pre-survey, word count of the responses ranges from 4 to 67 with a median of 22 words whereas for the post-survey, the range was 2-97 with a median of 15 words. It can be seen that after being exposed to the NAE Grand Challenges by working on the hands-on design project, students' understanding of engineers' roles went above and beyond "solving problems" and "designing"; more comments about the "social good" (including improving quality of life, making the world a better place) came up in the post-survey. It is also interesting to note that in the pre-survey, those who referred to engineers all used words like "engineers" or "they" whereas some in the post-survey referred to engineers as "we", indicating that the design project has to some extent helped with students' self-identification as engineers.

Table 2. Participants comments about roles engineers play in society (pre-survey, N=35, response rate: 87.5%)

Theme	Example	Frequency
Design/Create/ Innovate	*"Engineers contribute to the development of technologies that help society such as more efficient computers, technologies that encourage sustainability, or improved medicine."*	26

Problem Solving	*"Engineers help solve problems and work to improve aspects of society. Everything from the design and construction of structures to machines to energy to food, engineers are the problem solvers of society."*	7
Leaders	*"They can play the role as leaders because engineers tend to be open minded and usually are full with ideas that they could apply to society not only by helping but by also encouraging others as well."*	1

Table 3. Participants comments about roles engineers play in society (post-survey, N=44, response rate: 64.7%)

Theme	Example	Frequency
Design/ create	*"Engineers design new products, push scientific advancements into the real world, and help improve the living standards of society."*	31
Improve quality of life/make life easier/make the world a better place	*"Helping improve the overall quality of life by inventing systems that help improve the standard of a well being."*	11
Problem solving	*"Solving the worlds problems, building and designing new things to propel humanity toward a brighter future."*	4
Help underdeveloped nations & rural areas	*"Helping people in undeveloped nations become more advanced and modern."*	3
Leaders	*"Engineers play roles throughout all aspects of society. Engineers, due to their work ethic, can become leaders of companies or businesses due to their ability to manage and organize large projects. Also, engineers of individual disciplines contribute new ideas and technologies to advance society as a whole. "*	1
Working in teams	*"Engineers are all over, they are looking for new ways to fix old problems. For example, They are always teams doing work on buildings. Mechanical, structural, and electrical. There are also plenty of computer and software engineers that are reshaping the way technology is advancing. Chemical engineers also work with many plastics and have a huge impact in the oil industry. Engineering is everywhere."*	1
Social change	*"They can provide a social change based on a change in technology. This can be shown when vaccines were produced, when the car was created, and many others."*	1

Questions 7 and 8 were included in the surveys in order to gain insight on the extent to which students knew about the NAE Grand Challenges for Engineering and if this has changed before and after the design project. Figure 7 shows the results in aggregate form and there has been a significant increase in knowledge about the Grand Challenges from the pre- to the post-survey (p<0.01). As can be seen in Figure 8, significant gains in knowledge about the Grand Challenges were also observed for the 12 participants who completed both pre and post surveys (p=0.01).

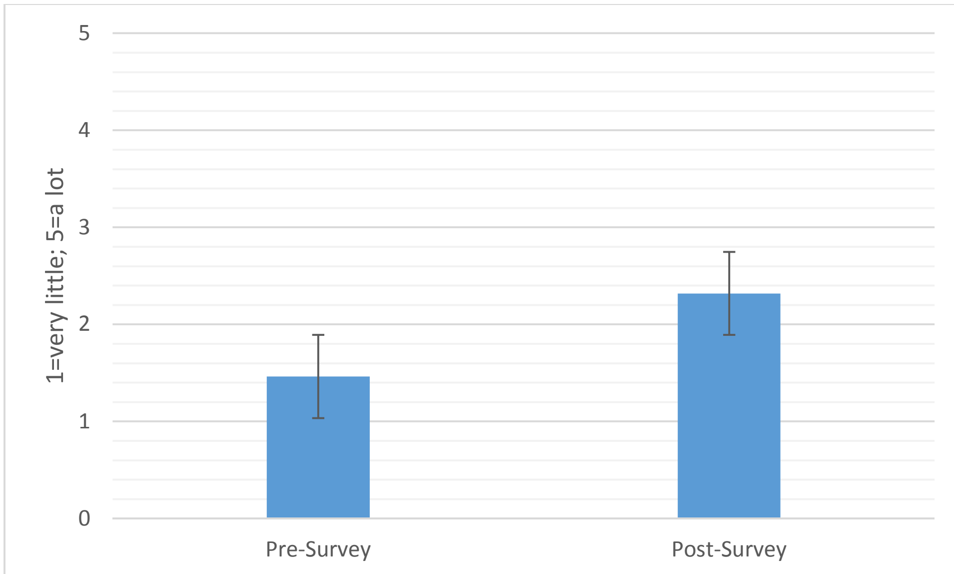

Figure 7. How much do you know about NAE GC pre- and post-survey results

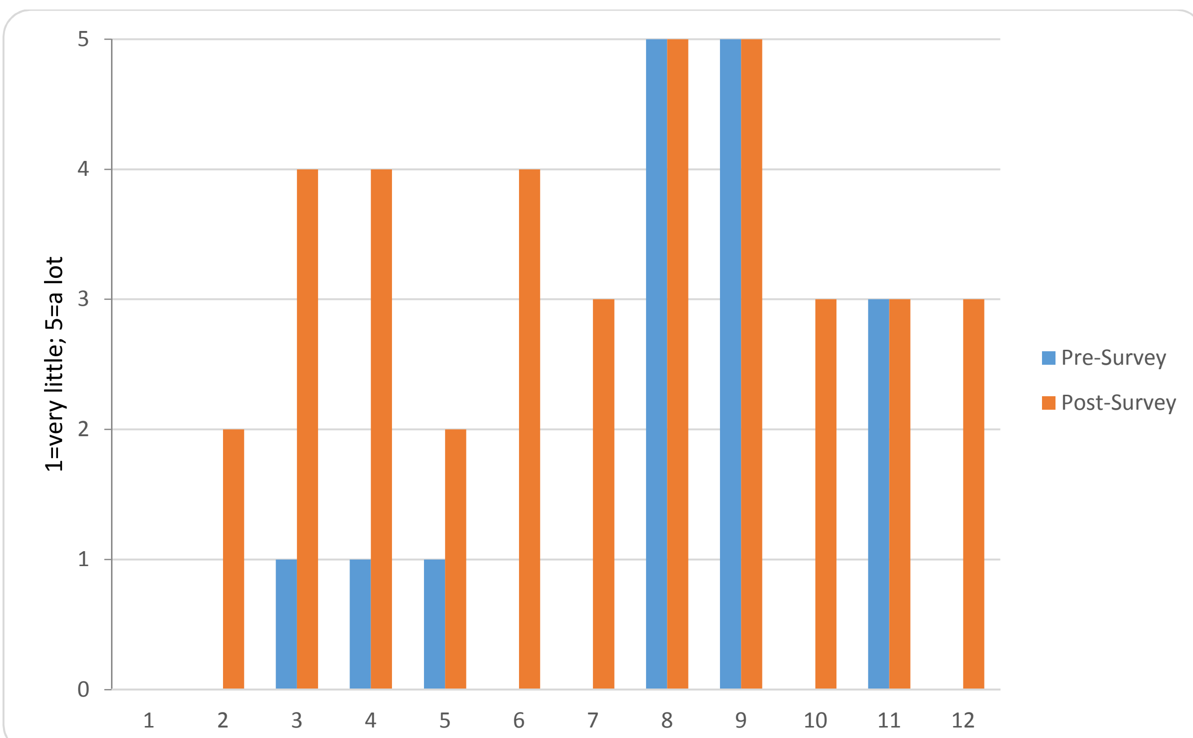

Figure 8. How much do you know about NAE GC pre- and post-results for 12 linked responses (no bar means the student answered ‘no’ to “Have you heard of the NAE GC?’)

Results of question 10 in the survey, as seen in Figure 9, show that the use of real world problems related to the NAE Grand Challenges was very effective at helping students better understand engineering in action.

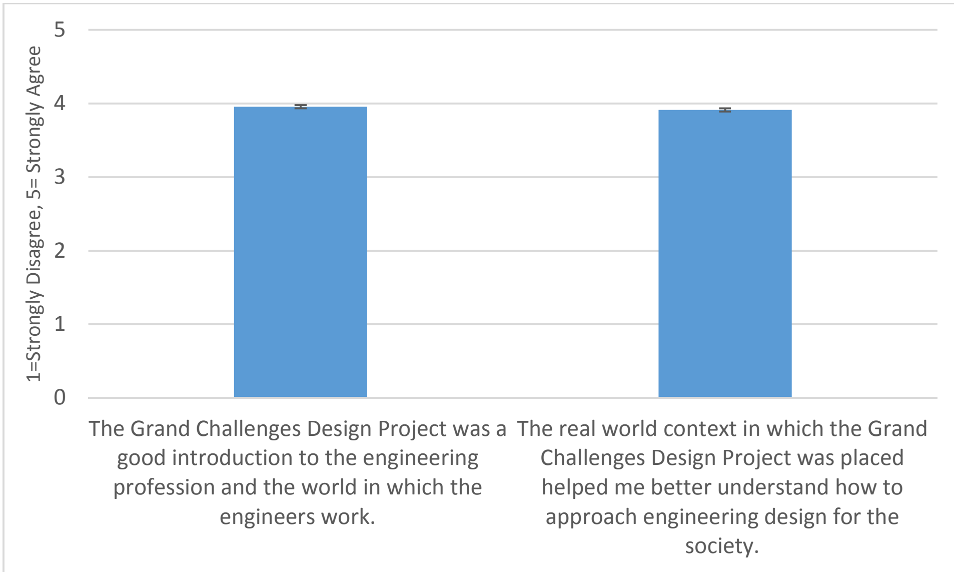

Figure 9. Impact of the NAE GC design project (post-survey only)

A total of 36 responses to the open-ended question “As a result of working on the Grand Challenges Design Project and learning about the Grand Challenges for Engineering, discuss and share an important example of learning, growth, and/or development that has occurred.” in the post survey were also coded using the same method as described before. A few of the common themes that were found included teamwork; learning more about engineering (for example, how to solve real world problems and how to work with constraints, such as budget and limited resources); and the importance of applying the engineering design process in solving problems.

Table 4. Comments about learning, growth, and/or development that has occurred (N=36, response rate: 52.9%)

Theme	Example	Frequency
Teamwork	*"The biggest thing that I learned was the importance of having the ability to work within a team. I learned that working with a team is a great way to accomplish effective solutions for problems; I also learned that you often have to compromise and be open to other ideas in order to get the best possible results."*	12
Learning more about engineering (solving real world problems, working with constraints, etc.)	*"We became more creative with the realistic conditions of a low budget and limited materials that we are able to work with in order to make a successful prototype. "*	9

Importance of the design process	*"As a result of working on the Grand Challenges Design Project and learning about the program itself has definitely enlightened me on the importance of the engineering design process and how diligently it must be followed. I thought, at first, that it was just a tedious rubric and outline that you forced up to follow, but I now understand that it is a very common and straightforward way to assess and work on engineering problems."*	6
Time management	*"This experience helped me learn time management and the importance of a team because sometime you can't do everything by yourself"*	3
Communication	*"I learned that I must be able to not only produce solutions to problems, but effectively communicate my solutions to others in order for it to become a reality."*	2
Diversity of solutions	*"An important growth of my character from learning the Grand Challenges Design Project would be to understand how changing and diverse engineering problems are. For a certain issue, there is always numerous approached to result in different outcomes. "*	1
Impact	*"I learned that I can influence and affect people with solutions that can help and benefit their way of life."*	1

Conclusions and Future Work

The NAE Grand Challenges for Engineering have been incorporated into the first-year Introduction to Engineering course to provide real world context for a hands-on team based design project. Even though quantitative results show that this incorporation did not seem to have an impact on students' motivation, it did increase students' knowledge about the Grand Challenges and positively impacted students' interest. Overall, both quantitative and qualitative results show that this real world context based on the NAE Grand Challenges has positively changed students' perception of engineers' roles and the impact of engineering solutions in the society, and has effectively helped students better understand the engineering profession and how to approach real world engineering problems.

Future plans for the project include incorporation of the other Grand Challenge areas into the design project to provide an increased variety of choices for students. In order to further assess the impact of this project on students, future studies may include a control group for comparison. In an effort to increase the response rate, surveys for future studies may be given during class instead of simply posting them online for students to complete on their own.

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Appendix A. Three Real World Scenarios for the Project

Scenario 1: Mawanga (pronounced Muh-Wang-ah) is located in the Busia District on the southern part of the Samia Region of Uganda. The 5,500 adults and 8,000 children in this village travel 2.5 kilometers each way to collect contaminated surface water from an open pond (an unimproved drinking water source). Despite the government’s efforts to educate and sensitize villagers on ways to safeguard drinking water, most villagers are semi-illiterate and the warnings are often ignored or go unheeded. Heavy rains often wash waste products into the open ponds; large waste particles are often found in these water sources. In addition, the water is cloudy with sediment (with a high turbidity level), and contains microorganisms and chemical contaminants.

A company has hired your team to design a sustainable and cost effective system that will provide Mawanga residents with safe, clean drinking water from their contaminated pond water. Your design will be commercialized by your company and be mass produced and marketed. Your design should be portable, light weight, easy to set up, and easy to use (with no special skills required). Your design can be manually operated or automatic. Natural resources (i.e. the sun) can be used for power if required, since electricity is not readily available everywhere in the village. The system should require minimal maintenance including infrequent replacement of parts and filtration media. You will be required to build and test a functional prototype of your solution (or a major part of the solution) and prove the effectiveness of your design quantitatively.

Scenario 2: The village of Salewuzeke is located by the Taklamakan desert in China. Electrical power supply has been a challenge in the village due to its remote location. The desert climate makes solar an abundant renewable energy source for the village and a nonprofit organization, Independent Energy Association (IEA), has provided PV (photovoltaic) solar cells to the villagers at a very low cost to help them gain access to electricity. However, the solar cells have not been efficient at generating electricity due to the changing position of the sun. The position of the sun changes continuously throughout the day and the villagers lack the knowledge and skills required to maximize the power output from them. Your team has volunteered to design a solar cell power plant that consistently maximizes the power output of the solar cells despite the sun's movement throughout the day. Your solar cell power plant design can be located anywhere in the village. The solar cell power plant should be durable and designed to provide power for many years with minimal maintenance. The solar cells should not come in close contact with the sun at any time (to prevent damage to the cells). You will be required build and test a functional prototype of your solution and prove the effectiveness of your design quantitatively.

Scenario 3: The Arizona Science Center is developing new hands-on exhibits to teach the general public scientific principles. They have asked your team to design a new interactive and fun exhibit appropriate for an age group of your selection. Your design should be effective in teaching the scientific principle to people with different learning styles and you should prove the effectiveness of your design in teaching the scientific principle quantitatively. Your design must be interactive (i.e. require audience participation, input, etc.), and must display quantitative results to the user (for example, if you were teaching F=ma, results may show quantitative force results for different values of input variables, i.e., different mass and acceleration values). The design may focus on one or more audiences at a time, and should be easily resettable for the next audience. You will be required to build and test a functional prototype of the exhibit and prove the effectiveness of your design quantitatively. Your exhibit should demonstrate one of the following principles:

- Conservation of Mass (mass in = mass out; total mass in closed system = constant)
- Conservation of Energy (potential energy + kinetic energy = constant)
- Conservation of Momentum
- Newton's Laws of Motion
- Hooke's Law for a spring (F=kx)
- Ohm's Law (V=IR)
- Projectile Motion
- Thermodynamics Laws (Newton's law of cooling, etc.)

Other scientific principles may also be acceptable; please talk to the instructor if you would like to demonstrate a principle not listed above. Examples of successful fun hands-on exhibits can be found at the xxxx Science Center and other science and discovery museums.

Appendix B. 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. What is your current academic standing?

- Freshman
- Sophomore
- Junior
- Senior
- Fifth year senior or more
- I prefer not to answer
- Other: ________________

3. What is your gender?

- Female
- Male

4. What is your major?

- Aerospace Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Science
- Electrical Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Other

5. 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.

6. Select an answer that best describes your opinion about each of the following statements.

(For each of the items below, survey participants selected one of: “Strongly Disagree,” “Disagree,” “Neither Agree nor Disagree”, “Agree,” or “Strongly Agree,”)

- The amount of effort it will take to get my engineering degree is worthwhile to me.
- Being good at solving engineering-related problems is important to me.
- Getting an engineering degree is essential to being the person that I want to become.
- I am becoming an engineer by working towards my degree.
- I want to become an engineer.
- I am an engineer.
- I am excited about engineering.
- Solving engineering problems is rewarding.
- I see how I can apply what we have learned in FSE100 to real life.
- I am aware of the challenges and opportunities that I will face as an engineer after I graduate.
- Having a global perspective is very important for engineers.
- I am confident that I could successfully design a solution for a community.
- Engineering solutions are affected by and should be responsible to limited resource availability.
- Engineers play a very important role in the society.

7. Can you give some examples of what kind of roles engineers can play in the society?

____

8. Have you heard of the National Academy of Engineering (NAE) Grand Challenges for Engineering?

- Yes
- No

9. If you answered "Yes" to the previous question, how much do you know about the NAE Grand Challenges for Engineering?

(Survey participants selected a number from 1-5 with 1 being very little and 5 being a lot)

10. Select an answer that best describes your opinion about each of the following statements:

(For each of the items below, survey participants selected one of: “Strongly Disagree,” “Disagree,” “Neither Agree Nor Disagree”, “Agree,” or “Strongly Agree,”).

The Grand Challenges Design Project was a good introduction to the engineering profession and the world in which the engineers work.

- The real world context in which the Grand Challenges Design Project was placed helped me better understand how to approach engineering design for the society.

11. As a result of working on the Grand Challenges Design Project and learning about the Grand Challenges for Engineering, discuss and share an important example of learning, growth, and/or development that has occurred.