# Work in Progress: An Interdisciplinary Course Designed to Assist First-Year Students in Planning and Preparing for Success in the NAE Grand Challenge Scholars Program

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## Abstract

This Work in Progress paper describes an interdisciplinary course for first year engineering students focused on exploring the National Academy of Engineering (NAE) Grand Challenges, and recognizing societal issues that influence engineering solutions to those challenges. This course is offered as a part of the NAE Grand Challenge Scholars Program (GCSP) at Arizona State University (ASU) to help students develop a personal plan for pursuing their interests in the program. The NAE GCSP is designed to prepare students to become the next generation of engineering leaders with a unique experience and skillset that includes hands-on research experience, interdisciplinary curriculum, entrepreneurship, global dimension, and service learning. The course described in this paper is one approach that could be used to help first year students to define and pursue their path toward becoming these future engineering leaders. At ASU, approximately 100 freshmen engineering students admitted into GCSP enroll in this interdisciplinary course each fall semester, which is taught in sections of up to 50 students. Through participation in this course, students develop an understanding of the interdisciplinary nature of the Grand Challenges and identify which challenges they want to focus their efforts on in their future in the GCSP. Students use digital portfolios throughout the course to reflect on their experience for each grand challenge theme area and their overall course experience, in order to relate their coursework to their interests and future plans. To prepare the students for their future in GCSP, students complete planning assignments which require them to meet faculty and develop a plan to complete the GCSP requirements.

The impact of this course on first year GCSP students' awareness of the Grand Challenges, their interests, and their confidence that they will complete the GCSP was assessed. A custom survey instrument was designed to measure students' familiarity with the Grand Challenges, GCSP requirements, and opportunities at ASU to complete GCSP requirements, as well as their confidence in their interests, future completion of the program, and having a plan to complete the program. Results indicate that this course is successful at meetings its goals of increasing students' familiarity with the Grand Challenges and the GCSP, and at helping them to identify their interests and become confident that they have a plan for completing the GCSP.


## Introduction

Preparing students to be globally competent engineers is an important task that many universities have taken on in recent years, many in the context of the National Academy of Engineering (NAE) Grand Challenge Scholars Program (GCSP) [1]. There are currently more than 30 universities with an active GCSP, and that number is increasing with the growing need for engineers with broader perspectives and skillsets [1]. In early 2015, over 120 U.S. engineering schools signed a commitment letter to President Barack Obama to prepare a total of at least 20,000 students over the next decade with experiences and accomplishments similar to those in GCSP[2]. Students in the GCSP gain experience in research, interdisciplinary, entrepreneurship, global, research, and service learning to gain a broader perspective of the NAE Grand Challenges

for Engineering[1, 3]. Each student chooses an overarching Grand Challenge theme for their experiences in the program, and selects their own path through the program. Students in the GCSP at ASU choose one specific Grand Challenge or a Grand Challenge theme area (energy, sustainability, education, security, health) as their focus in the program. Although each GCSP has its own requirements that serve as a framework to guide students in completing all of the components of the program, additional formal efforts to provide assistance and direction to students in completing the program components have not yet been reported on. At ASU, several efforts have been made to support students as they progress through the GCSP from when they are accepted into the program as freshmen through graduation. Efforts made to support students in the GCSP include an optional weeklong residential summer program, lab tours, opportunities for students to interact with faculty in small and large groups, social events, and an interdisciplinary course for freshman students in the program which will be described here.

Many first year engineering students have not yet defined their specific interests in the engineering field, and would benefit from opportunities that encourage them to explore different areas to find what they are most passionate about. This can be done by providing students with open-ended assignments such as research papers in which they choose what subject they want to learn about based on their interests. Reflection is also an important practice that can help students to relate course material to their interests[4]. Recently, there has been a growing interest in students creating portfolios to showcase their work, and reflect on their experiences, interests, and growth[4-7]. In a self-directed program such as the GCSP, it is especially important to provide guidance to help students to develop plans to pursue their interests and meet their goals.

At ASU, an interdisciplinary course taught to first year students in the GCSP has been offered for the past several years in an effort to help to prepare students for success in the program. This course helps students to become familiar with the interdisciplinary, global nature of the Grand Challenges, and provides them with opportunities to explore their interests and develop plans for their future in the GCSP. This paper will describe the course outcomes, structure, and content, and will present results from a survey conducted to evaluate the effectiveness of the course.

## Course Design

The interdisciplinary course, Perspectives on Grand Challenges for Engineering, is designed for new GCSP students of all engineering majors. Each fall semester, approximately 100 freshmen students enroll in this course which is taught in sections of up to 50 students. The 3 credit hour course meets twice a week for 75 minutes per session, and is taught in an active learning environment that requires student participation in discussions, activities, and a team project. The course is centered on the theme of the National Academy of Engineering's (NAE) Grand Challenges for engineering in the 21st century and it is designed to offer students an opportunity to develop an interdisciplinary appreciation for the Grand Challenges and to increase students' awareness of the social complexities of meeting the needs of local and global challenges through engineering and technology. In this course, students also learn more about the GCSP, identify their interests, and begin their path towards making a Grand Challenge area their life's passion. Students also begin creating a plan to complete the program components during their undergraduate studies.

The specific course objectives are:

1. Develop an interdisciplinary understanding of the global engineering Grand Challenges that human societies face in the 21st century.
1. Describe the research themes at ASU, and locate ongoing research at ASU in all Grand Challenge theme areas.
2. Identify opportunities to create added value in the Grand Challenge areas, and conceptualize a potential future solution.
3. Interpret why (and in what ways) a technology/design solution adds value from multiple perspectives (technological, sociocultural, economic, environmental, global, etc.), and describe a design solution in terms of its societal value (as well as its technical features and function).
4. Demonstrate an awareness of societal issues (e.g. sociocultural, political, economic, environmental) that influence and/or constrain engineering solutions.
5. Create a preliminary plan of study for completing the five components (research, interdisciplinary, entrepreneurship, global, service learning) of the Grand Challenge Scholars Program during their undergraduate career.

The course structure, activities, and assignments are carefully designed to achieve these objectives. Specifically, the majority of the course is organized around exploring the interdisciplinary, global nature of five Grand Challenge theme areas: Energy, Sustainability, Health, Security, Education/Tools for Scientific Discovery. Students learn about technical engineering solutions in each theme area and the societal (social, cultural, economic, political, legal, etc.) factors that can influence engineering solutions or be influenced by them. This course, thus, provides students with an opportunity to explore the many dimensions of the Grand Challenges and helps them to identify what they are interested in focusing their work on in the future.

To help students learn more about the interdisciplinary Grand Challenges for Engineering and to identify or confirm their interests, students first participate in an introductory activity to create an overview of the Grand Challenges, and then explore the challenges in each of five Grand Challenge theme areas over the course of several weeks. In the introductory activity, students work in groups and utilize various resources to create a mind map for one of the assigned Grand Challenge theme areas to show the specific challenges the world is facing and how they are related. Students are encouraged to think broadly about the challenges, including both technical and nontechnical problems, and how they relate to each other. Following the introductory activity, each of the five Grand Challenge theme areas (energy, sustainability, health, security, education/tools/virtual reality) is discussed in greater detail using a three-lecture series: a faculty guest lecture, discussion/activity, and student presentations about related research. The class discussions/activities for the theme area lecture series emphasize the societal issues that influence and/or constrain engineering solutions. These theme area discussions/activities have included an energy economics game, a hands-on bridge design activity, class debates about medical applications including bionics and nanobots, a security crisis role playing simulation, and an IoT (Internet of Things) design activity. For the student presentations, each student chooses a Grand Challenge theme area based on their interests, researches examples of current work being done in that area, and presents one of the examples to the class. This presentation is part of a larger assignment, an individual research paper, in which students learn about and

describe three examples of work being done in the area, including one from ASU, and discuss potential societal challenges and impact of implementing the work. To help students delve deeper into solving a specific problem in one of the Grand Challenge areas, they also work on a team project focused on developing conceptual engineering solutions that may exist in the future. In that project, students work in groups to identify an opportunity to address a specific problem based on their interests, develop a conceptual futuristic solution, show technological advancements needed for the solution based on current technologies, and identify non-technological challenges and societal implications of their solution.

To further assist students in identifying and/or confirming their personal interests in the Grand Challenges and the GCSP, students are asked to reflect in a digital portfolio throughout the course. After exploring each of the Grand Challenge areas, students are asked to document and reflect on their experiences, specifically focused on how the experiences relate to their interests. Students are asked to think about what they did, how the experience relates to them and their interests, and what future actions they plan to take to apply what they've learned. At the end of the course, students complete a final reflection on their experience in the whole course including how it is has impacted their interests and their future in GCSP. These portfolio reflections are aimed at helping students to think more deeply about how what they are learning in class relates to them and their interests, in order to help them to make decisions in planning for their future.

To encourage students to learn more about the GCSP at ASU and begin developing a plan to complete the program, an initial class activity and several individual planning tasks are also included in the course. First, to become familiar with the specific GCSP requirements, students engage in a jigsaw activity to learn about the specific program requirements. To help students continue to work toward developing a plan for completing the GCSP, students complete three planning assignments over the course of the semester. The first planning assignment requires them to review the program manual. The second one asks them to identify ASU faculty members whose research interests them and meet with one to further learn about their research and seek possible research opportunities. For the third one, students create a plan to outline specific co-curricular and extracurricular activities that they plan to be engaged with each semester in order to complete each of the specific program requirements before they graduate.

**Assessment Methods**

A custom survey instrument was designed to assess the impact of this course on first year GCSP students' awareness of the Grand Challenges, their interests, and their confidence that they will complete GCSP. The survey was administered once at the beginning of the semester (pre-survey) and once at the end of the semester (post-survey) to students in four sections of this course in the fall 2016 semester. A total of 89 students (86% response rate) participated in the pre-survey and 43 (42% response rate) in the post-survey. Out of these participants, there were 33 students who completed both the pre and post surveys. The lower participation rate in the post-survey is probably due to the fact that the post-survey was given to students toward the end of the finals week and students may have lacked motivation to complete the survey.

The survey includes questions that measure students' familiarity with topics related to the GCSP and their confidence in their future plans for GCSP. Specifically, the survey asks students to rate

their familiarity with the Grand Challenges, GCSP requirements, opportunities at ASU to complete GCSP, and Grand Challenges related research at ASU, as well as their confidence in their interests in a specific Grand Challenge theme area, future completion of the program, and having a plan to complete the program, on a Likert scale of 1-5 (1 being not at all familiar/confident and 5 being extremely familiar/confident). Students were also asked to rank the Grand Challenge theme areas based on their interests. The students were also asked whether they had previously attended the GCSP summer program offered at ASU, as that program also provides them with a brief introduction to the Grand Challenges, the GCSP, and some related work at ASU.

**Results and Discussion**

The participants in this study were all engineering students recently admitted to the GCSP. The majority of the participants self-reported that they had freshman standing (84 of 89 for pre-survey, 41 of 43 for post-survey), 4 were sophomores, and 1 senior. The results from the senior were excluded from the data analysis because she has already completed most of the requirements of the GCSP and thus her familiarity and confidence related to the GCSP were already at the maximum level in the pre-survey. Therefore, the results presented here include analysis of 88 responses to the pre-survey and 42 responses to the post-survey. Approximately 35% of participants who completed the pre-survey had previously attended the GCSP summer program offered at ASU, including 14 of the 32 participants who completed both the pre and post surveys. Nearly all of the engineering disciplines were represented in the study population, as can be seen in Figure 1 below.

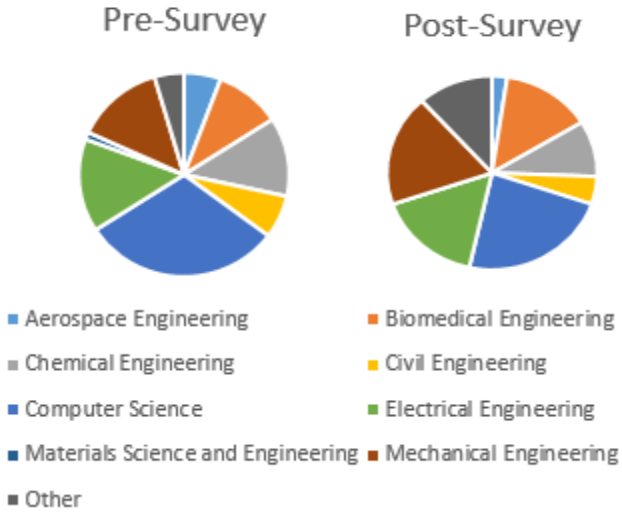


Figure 1. Participants' majors

Results were analyzed by calculating and comparing mean scores for pre- and post- survey responses for each of the Likert scale questions. The 32 linked pre- and post- survey responses were also compared. Since some participants may have had prior exposure to the Grand Challenges and the GCSP through participation in the GCSP summer program offered at ASU which could affect their survey responses, linked responses for those who attended the summer program were analyzed separately from those who had not.

Figures 2 and 3 below compare the mean pre- and post- survey responses for all participants regarding their perceived familiarity with GCSP related topics and opportunities, and their confidence in their future plans for the GCSP. As seen in Figure 2, participants' familiarity with the Grand Challenges, GCSP requirements, opportunities at ASU to complete GCSP requirements, and GCSP related research at ASU all increased as a result of completing this course. These results indicate that the course was effective at meeting its objectives related to helping students to become familiar with the Grand Challenges, the GCSP, and opportunities that students can pursue at ASU to complete the GCSP requirements. Similarly, as seen in Figure 3, participants' confidence in having a plan to complete each of the GCSP requirements also increased. This is another positive result, as it indicates that the planning assignments, which require students to identify specific courses and experiences they are interested in possibly completing for each of the GCSP components, are effective at helping students to develop a plan for their future in the GCSP.

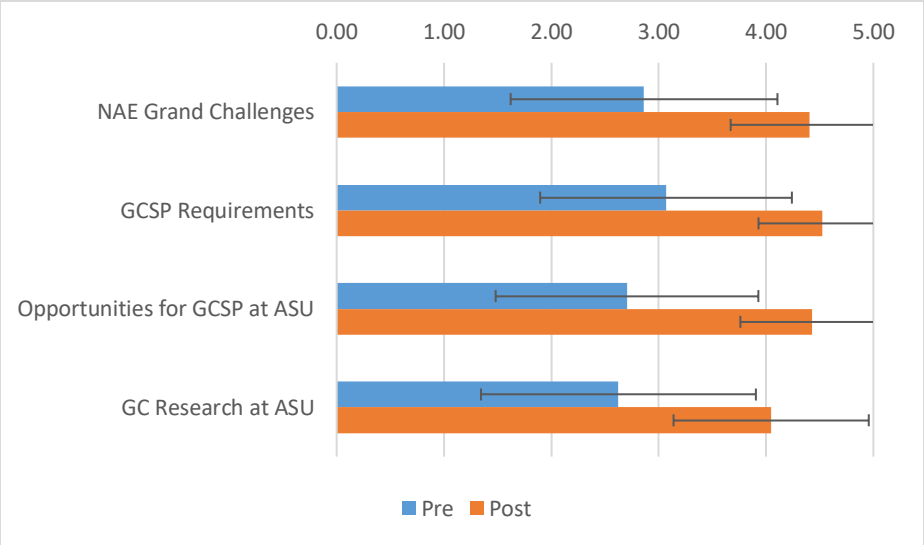


Figure 2. Unpaired pre- and post-survey results of participants' familiarity with the Grand Challenges, GCSP, and opportunities (all participants; pre (N=88), post (N=42)). Error bars represent +/- one standard deviation.

In the survey, participants were also asked to rank the Grand Challenge theme areas in order of their interest. As a complement to that, participants were also asked how confident they were that they would continue to pursue their current first choice theme when completing the GCSP. Results show a small increase in confidence in their first choice from pre- to post-, which indicates that students may still not be completely sure of their interests after they have completed this course. This is not surprising, as these students took this course in their first semester of college and thus are still identifying their goals and interests. One interesting result was that participants' perceived confidence that they will complete the GCSP started out high (mean=4.03) before the course, and remained near the same level at the end of the course (mean=4.07). One possible explanation for this might be that students in this program are high-achieving, motivated students who perhaps exhibit more confidence that they will complete any program they sign up for when they start their college career. A comparison of the 32 linked

results showed similar trends to those seen for the entire sample population, and thus are not included here.

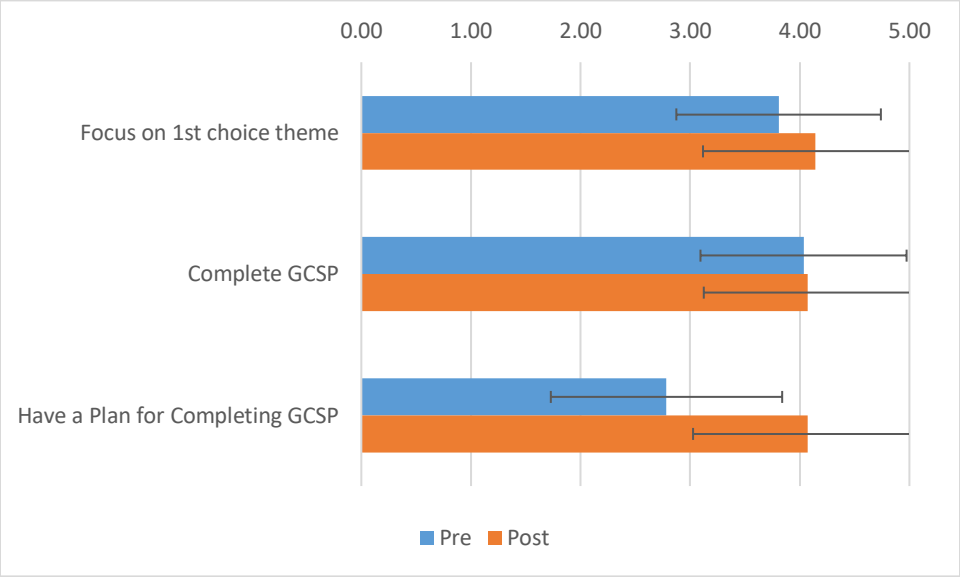


Figure 3. Unpaired pre- and post-survey results of participants' confidence in their plan to complete GCSP (all participants; pre (N=88), post (N=42)) Error bars represent +/- one standard deviation.

Out of the 32 linked responses, 18 did not participate in the Summer Institute program before taking this course and 14 did. Results show that the impact of this course on these two groups of participants is different. Figures 4 and 5 below show the differences between the mean scores for the linked pre- and post- survey responses for those who did not participate in the Summer Institute program; and Figures 6 and 7 are for those who attended the Summer Institute program. It can be seen that those who did not attend the Summer Institute program had a greater increase in their knowledge about the NAE Grand Challenges, learned more about GCSP requirements and opportunities for GCSP at ASU, and became more aware of Grand Challenge related research at ASU. This is expected because the weeklong summer program provided participants with a brief introduction to each of the five Grand Challenge theme areas, GCSP requirements, and some research work at ASU; therefore those who participated in the summer program already had some knowledge in these areas at the beginning of the course, resulting in a smaller gain in their responses regarding their perceived familiarity with GCSP related topics and opportunities from pre- to post- surveys. However, very similar results are found between these two groups of participants regarding their confidence of their future plans in the GCSP.

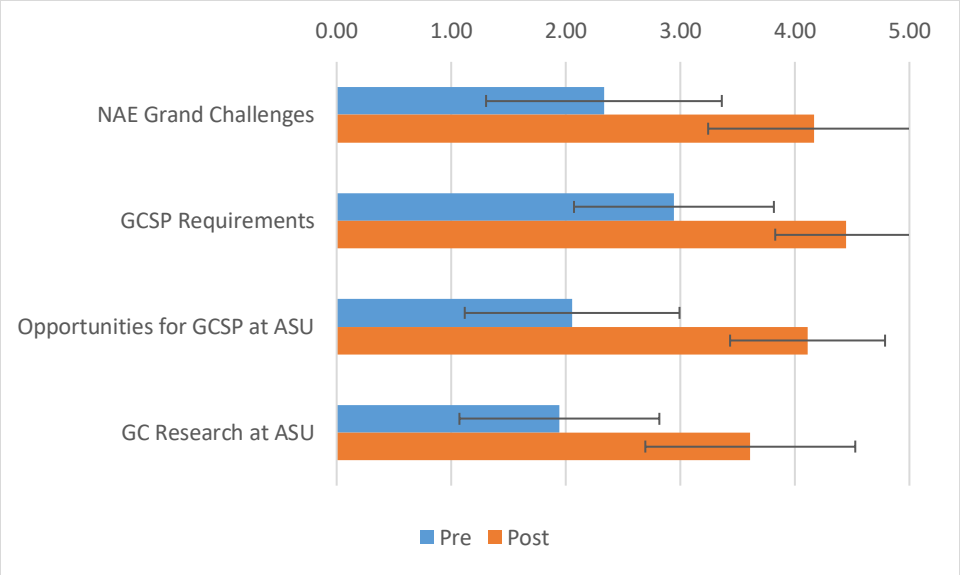


Figure 4. Linked pre-and post-survey results of participants' familiarity with the Grand Challenges, GCSP, and opportunities (without summer program, N=18). Error bars represent +/- one standard deviation.

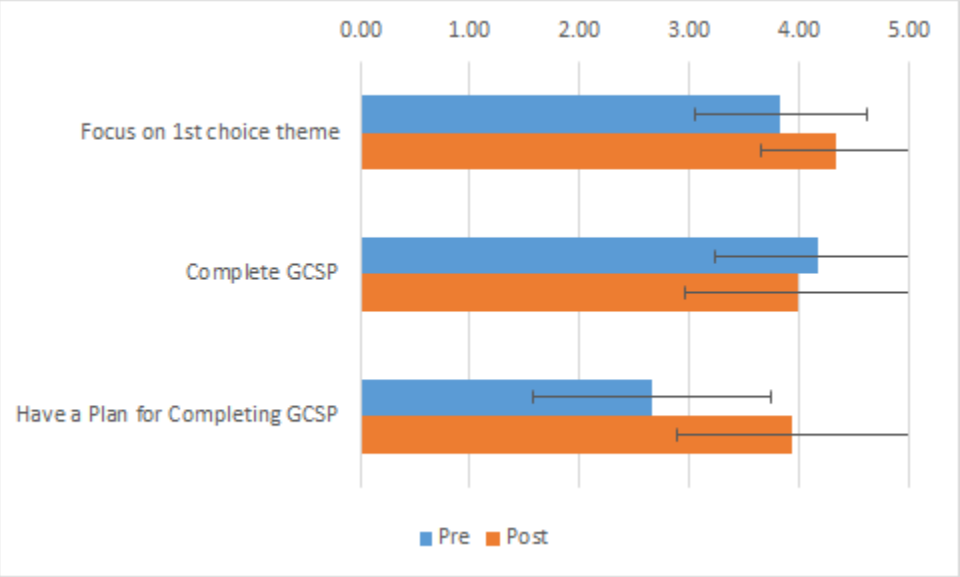


Figure 5. Linked pre-and post-survey results of participants' confidence in their plan to complete GCSP (without summer program, N=18). Error bars represent +/- one standard deviation.

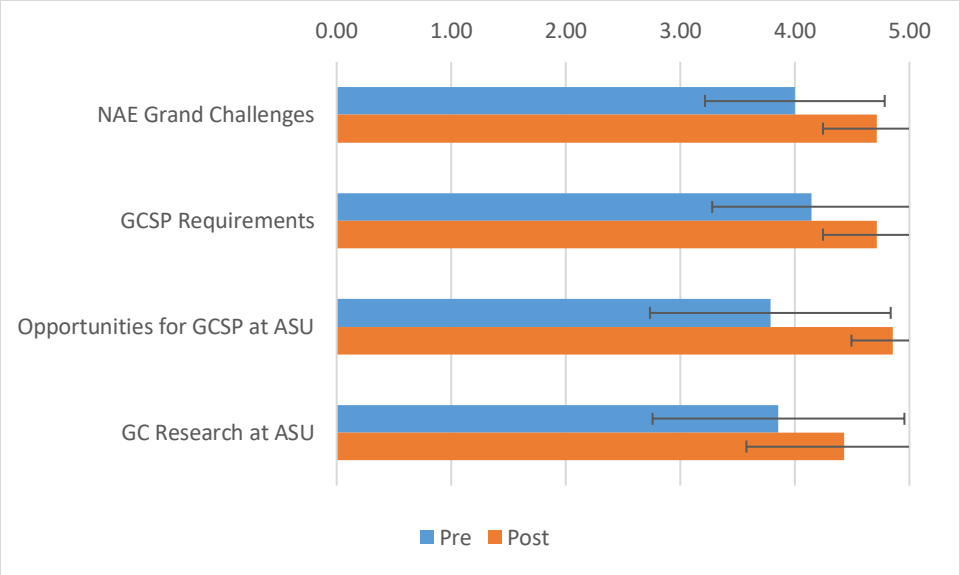


Figure 6. Linked pre-and post-survey results of participants' familiarity with the Grand Challenges, GCSP, and opportunities (with summer program, N=14). Error bars represent +/- one standard deviation.

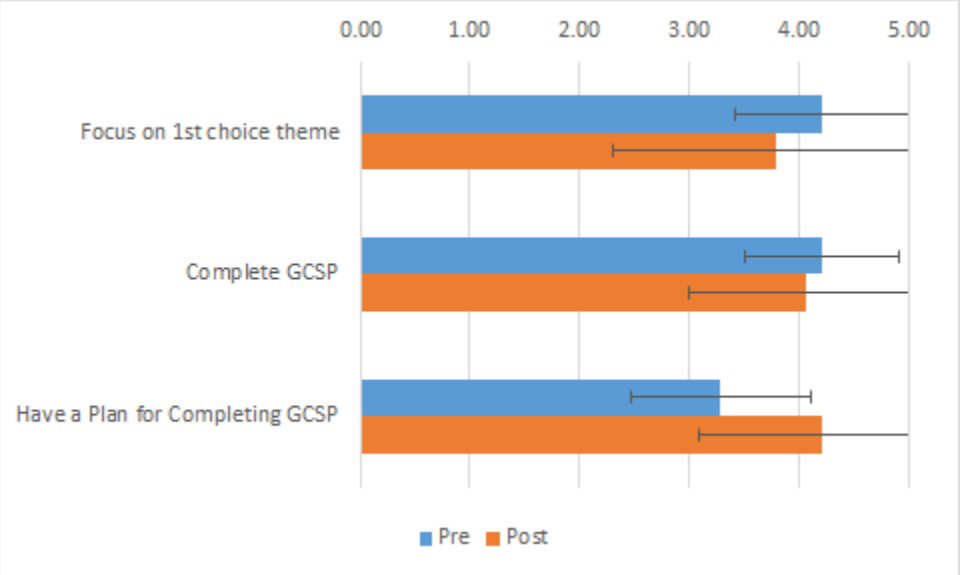


Figure 7. Linked pre-and post-survey results of participants' confidence in their plan to complete GCSP (with summer program, N=18). Error bars represent +/- one standard deviation.

In addition to the Likert-scale questions, participants were also asked to rank their interests in six different Grand Challenge theme areas (Education, Energy, Health, Security, Sustainability, and Tools for Scientific Discovery). One interesting result that was found when looking at the linked survey results for this question is that there were several participants who changed these rankings from pre- to post- indicating that the course influenced their interests. The table below shows the numbers of participants who changed their first or second choice theme area and those who did not change these choices. It is interesting to note that most of those who changed their first

choice theme areas made a significant change, for example, changing from energy to tools of scientific discovery, or from sustainability to education.

Table 1. Pre- and post-survey results of participants' top two choices of GC themes

| | Number of Participants (linked responses only, N=32) |
|---|---|
| Changed First Choice Theme | 7 |
| Changed Second Choice Theme | 17 |
| Did not Change First or Second Choice Themes | 12 |

The final question asked in the survey was aimed at indirectly measuring the effect this course had on helping students to meet other students in the GCSP and thus begin to build community with other scholars, by asking participants how many students they know in the GCSP. Table 2 below compares the responses for the pre- and post- survey for those participants who completed both surveys (linked responses). As can be seen in the table, the percentage of participants who knew at least 6 other GCSP students increased from approximately 41% to 84% from the beginning to the end of the course. It is important to note that all 10 participants who indicated that they knew more than 15 students in the pre survey participated in the GCSP summer program, and thus had already met many other GCSP students there.

Table 2. Number of students in GCSP that participants know

| Number of students that participants personally know who are also in GCSP | Number of responses (pre-survey, linked responses only, N=32) | Number of responses (pre-survey, linked responses only, N=32) |
|---|---|---|
| 0-2 | 13 (42%) | 2 (6%) |
| 3-5 | 6 (19%) | 4 (13%) |
| 6-8 | 1 (3%) | 7 (23%) |
| 9-11 | 1 (3%) | 6 (19%) |
| 12-15 | 1 (3%) | 1 (3%) |
| more than 15 | 10 (32%) | 12 (39%) |

**Conclusions and Future Work**

An interdisciplinary course has been designed for new GCSP students at ASU to help freshman engineering students develop an understanding of the interdisciplinary nature of the Grand Challenges and to identify which challenges they want to focus their efforts on in their future in

the GCSP. The majority of the course is structured around five Grand Challenge theme areas (energy, sustainability, security, health, and education), and class activities are designed to help students learn about each of the global engineering Grand Challenges theme areas, including the societal complexities of these challenges as well as how non-technological factors may affect the development and implementation of engineering solutions. Students listen to faculty members discussing their research in these areas in class, write a research paper about three examples of work being done to address the challenges in that area, and present one example to the class. They also participate in a group project to develop a futuristic solution to a problem in one of these areas, focusing on both the technological and societal aspects of their solution. Throughout the course, students keep a digital portfolio to document and reflect on their experiences and connect the course materials to their interests. The course also provides various opportunities to help students learn about GCSP requirements, identify opportunities at ASU that help them complete GCSP, and develop a plan to complete the program before they graduate.

This course has been shown to be effective at meeting its outcomes related to increasing students' knowledge about the Grand Challenges, and helping students to develop a plan to be successful in the GCSP. Specifically, the course has been shown to have greatly improved first year GCSP students' familiarity with the Grand Challenges, program requirements, opportunities at ASU to complete GCSP, and ongoing research at ASU. The course has also increased students' confidence that they have a plan for completing the program requirements. This course has provided first year students with an opportunity to explore the different Grand Challenge areas which helps them to identify or confirm which Grand Challenge area to focus their efforts on in their future in GCSP. The course also helped build a community among the first year GCSP students, which will enable them to support each other in the GCSP in the future.

Areas of future work include using a qualitative approach to better understand the impact this course has on students' perspectives and interests through analysis of students' digital portfolios. Students' final portfolio entries for the course, which are focused on their overall experience in the course, will be examined to investigate how their interests have changed, and how they have developed a more interdisciplinary understanding of the Grand Challenges. Portfolio entries completed for each Grand Challenge theme area may also be analyzed to investigate how the specific course activities have influenced students' interests and how they have contributed to students' understanding or awareness of the interdisciplinary nature of the Grand Challenges.

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