



## **Use of the National Academy of Engineering's Grand Challenges for Engineering as a semester-long project for an Introduction to Engineering course**

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## **Abstract**

The Grand Challenges for Engineering that have been identified by the National Academy of Engineering (NAE) are the basis of a semester-long project within an Introduction to Engineering course. Each section of the Introduction to Engineering course was split into groups of four to five students, with each group investigating one of the fourteen challenges. There were various assignments on this topic for each group to complete over the course of the semester. They started by identifying the types of engineers that would be involved in addressing their challenge, as well as identifying the non-engineering professionals that would also need to be involved. They completed a literature review of their topic and submitted an annotated bibliography from their literature review. They then wrote up a summary of their topic, using the information they had gathered, and finally ended the course with a presentation of their Grand Challenge topic.

These assignments based on the NAE's Grand Challenges for Engineering were used to introduce students to the diverse fields of engineering as well as to develop skills in finding and reviewing technical information, presenting information in written form, and preparing and making presentations, all while working as a part of a team. This project was designed to meet many of the course objectives as well as to develop skills that will be needed in many of their future engineering classes.

This paper presents an overview of the project and individual assignments as well as the outcomes and feedback from the students that participated in the project. The plans for further modifications and improvements to this project and assignments will also be presented.

## **Introduction**

The Introduction to Engineering course at Grand Valley State University (GVSU) is a one credit course that is designed to be an introduction to engineering as a career. It discusses the major fields of engineering and the typical responsibilities of an engineer. By the end of the semester, it is expected that the students have an understanding of: how to achieve success as an engineering undergraduate student at GVSU; the expectations of learning outcomes achieved through GVSU's engineering program; the engineering profession; and the nature of the world in which engineers work. These objectives are similar to other Introduction to Engineering courses that focus on introducing the career of engineering as well as skills required to be successful in future engineering courses.<sup>1-3</sup> As with some other Introduction to Engineering courses, it is not a required course for graduation from the engineering program.<sup>4</sup> Some of the skills taught in this class include effective studying techniques, time management, reviewing literature, working with a team, and giving presentations. Rather than focusing on "hard" (technical) skills, the skills emphasized in this class are related to the ABET "professional" skills: an ability to function on multidisciplinary teams (3d); an understanding of professional and ethical responsibility (3f); an ability to communicate effectively (3g); the broad education necessary to understand the impact

of engineering solutions in a global, economic, environmental, and societal context (3h); a recognition of the need for, and an ability to engage in life-long learning (3i); and a knowledge of contemporary issues (3j).<sup>5</sup>

In their analysis of teaching and assessing of ABET professional skills, Shuman et al. propose that “the mastery of these professional skills combined with an ability to innovate will add sufficient value to U.S. engineering graduates so that price does not become the primary determinant of who is hired in the global marketplace”.<sup>6</sup> Therefore, a project was developed as a framework to utilize these skills. The project was based on the National Academy of Engineering (NAE) Grand Challenges for Engineering. The fourteen Grand Challenges for Engineering, as determined by a committee of the NAE are:<sup>7</sup>

- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

This paper discusses the individual components of the semester-long team project using the Grand Challenges for Engineering as the context to develop professional skills and learn about the different fields of engineering. It will also present results from a survey of the students’ perceptions of the project and how the project should be modified for future classes.

### **Organization of the Project**

The students were split into teams of four to five members and each team was assigned one of the Grand Challenges for Engineering as the topic for their project. In order to guide the students through the process of gathering and presenting information about their topic, there were four different components to the project that were each a different assignment. The four assignments were due at different points over the entire semester.

After the teams were formed and the topics were assigned during the second week of the course, the first assignment for the project was a written assignment in which they were to introduce the Grand Challenge for Engineering that was assigned to their group. They had to also identify the types of engineers and non-engineers that are needed to address the challenge and explain how the various people would need to be involved.

The second assignment was to prepare an annotated bibliography. Rather than simply asking the students to find a number of sources that were relevant to their topic, they were also asked to review the sources and write a brief summary of the information presented in the sources. This encouraged them to consider the relevancy of the information and then to describe the information in their own words by preparing the summary. This assignment was due by the fourth week of the semester to encourage the teams to gather information on their topic well before the final components of the project were due.

Two weeks before the teams had to give their final presentation on their topic, they were required to prepare a written summary of their project. Within the summary, they were asked to describe the Grand Challenge for Engineering that was the topic of their project, identify what has already been accomplished in addressing the challenge, identify what still needs to be accomplished, and finally to explain how society will benefit from the work that engineers will do to address their specific topic.

The final component to the project was to complete an in-class presentation with their team. During the presentation, they were to present all of the information that was gathered over the entire semester as parts of the various assignments for the project. It was also required that each team member present a portion of the information. During the final presentations, teams that were not presenting were also asked to complete peer evaluations of the other presentations.

### **Assessment of the Project**

After completing the final presentations, the students were asked to provide feedback in the form of a perception survey. The feedback allowed the students to respond on a Likert scale within the range of agreement with the statements in the survey instrument from “not at all” to “extremely”. The survey questions and the response ratings are provided in Table 1. Although there were 56 students in the class section, only 38 students chose to complete the survey. The students that did choose to participate in the survey read and signed a consent form. To ensure confidentiality, there was no personally identifiable information collected on the survey forms.

From the feedback for question 1 that assessed the clarity of purpose and expectations of the assignments, the greatest number of respondents indicated that they “mostly” agreed with the statement, with all responses ranging between “moderately” and “extremely”. Question 2 assessed the organization of the assignments. Here again, the greatest number of respondents indicated that they “mostly” agreed with the statement, with all responses ranging between “moderately” and “extremely”. The third question assessed the helpfulness of working as a team. Although the majority of the respondents indicated that they “extremely” agreed with the statement in this question it had a slightly lower average rating than the previous questions because there was a much broader range to the answers, with all possible answers being selected from “not at all” to “extremely”. For question 4 that assessed how well the project introduced the engineering profession and the world in which engineers work, the greatest number of respondents indicated that they “mostly” agreed with the statement, with responses ranging between “somewhat” to “extremely”. The final two questions (questions 5 and 6) assessed how well the project helped develop written and oral presentation skills as well as information gathering skills to help the students be successful in their academic careers. The greatest number

of respondents indicated that they “mostly” agreed with the statements for both of these questions, with all possible answers being selected from “not at all” to “extremely”.

**Table 1.** Student ratings ( $\bar{X} \pm 1 SD$ ) for the “Grand Challenges for Engineering” Project – Students’ Perception Survey

Question	Rating (n = 38)
1. Information about the purpose and expectations of the assignments based on the Grand Challenges of Engineering were clear.	4.3 ± 0.6
2. The topics of the assignments pertaining to the Grand Challenges of Engineering project were arranged in a logical manner.	4.3 ± 0.1
3. Working as part of a team on the Grand Challenges of Engineering project was helpful.	4.1 ± 1.2
4. The Grand Challenges of Engineering project was a good introduction to the engineering profession and the world in which engineers work.	3.8 ± 0.8
5. The Grand Challenges of Engineering project helped me develop written and oral presentation skills that will help me be successful in my academic career.	3.6 ± 1.1
6. The Grand Challenges of Engineering project helped me develop information gathering skills that will help me be successful in my academic career.	3.6 ± 1.1

Possible responses for all questions were: 1 = not at all, 2 = somewhat, 3= moderately, 4 = mostly, 5 = extremely.

In addition to the Likert scale used to obtain responses for each question, there was also an opportunity for the students to provide comments pertaining to each question. The greatest number of comments came from the question that pertained to working as part of a team (question 3). While 21 out of the 38 respondents indicated that working with a team was extremely helpful, there were two students that found working with a team was not helpful at all. The comments indicated that some students found dealing with group members to be “an inconvenience”, there were scheduling/time constraints that made it difficult to work with the team members, and certain students completed most of the work. However, there were also comments that indicated that they “really enjoyed working with [their] team”, “this project helped [the student] work with others” and “made interaction with a group easier”.

To help the students gather information for their projects, a librarian from the GVSU Libraries completed a workshop with the students during one of the class periods. There were a number of comments made by the students that indicated that this was quite helpful and that learning how to access the online databases and journals was helpful for this project and for their future academic career.

During the final presentations, teams that were not presenting were asked to complete peer evaluations of the other presentations. A grading rubric was provided, which was the same rubric that the instructor used to evaluate the presentations, and the students were able to provide their feedback as well. The rubric was distributed prior to the presentations so that the presenters were aware of the grading criteria while preparing for the final presentations.

All of the assignments that composed the Grand Challenges for Engineering project were graded. The first three assignments, to introduce their topic, complete the annotated bibliography, and prepare the summary of their topic, were worth 5% of their final grade per assignment. The final presentation was worth 20% of their final grade for the course. Therefore, all four components of the project were worth a total of 35% of their final grade for the course. The average grade for all groups on the overall project was a B. From the signed consent forms, it was noted that the average grade for the students that completed the survey was a B+, while the average grade for the students that chose not to complete the survey was a C.

### **Updates for Future Classes**

In general, the feedback about this project was quite positive. The use of the Grand Challenges for Engineering as the topics of the project provided interesting subject matter for the students to investigate while providing the opportunity to develop a number of professional skills and learning about the different fields of engineering.

The greatest issues encountered were due to the requirement for the students to work as part of a team. When the teams were formed, most students just turned to other students near them and formed teams. In the future, it would be helpful to ask the students to provide some information about their schedules and interests in order to use the information to form teams that may be able to work together more effectively. Once the teams are formed, a team contract could be prepared and signed by all team members that would outline exactly what is expected from all members and how any disputes will be handled. This will allow the students to deal with any problems within their group before it escalates to involving the instructor.

After the first two assignments for the project, some teams had indicated that they were having problems with members that were not contributing to the work. For the written project summary (third assignment for the project), each team member was able to indicate on the assignment exactly which portion of the work was their contribution. Each member was then able to be graded on their individual work. If all team members had contributed equally and wanted to share the overall grade for the team, they were not required to indicate which team member contributed each portion of the work. For the final presentation, each team member was required to participate in the presentation in order to receive a grade. This also helped to alleviate problems with some students not contributing to the work of the team. In the future, these options could be made available to the students on all of the assignments that are a part of this project. This will allow the team to assign roles to individual members so that they must all participate in order to complete the assigned tasks. Also, giving the members the opportunity to evaluate the contributions of each could also help to improve the accountability of each team member. However, the fact that the students have to work with a team of people that they may not always get along with or where others may not always get their work completed can be used as a teaching opportunity. In their future careers as engineers, they will not always get to choose who they work with and personality clashes and workload issues will be real situations that they will have to deal with.

The students focused on the technical aspects of the Grand Challenges for Engineering. The non-technical controversies around some of the grand challenges can provide an increased level of complexity when considering these challenges. Having the students consider multiple aspects for their topics, including the viewpoints of people that may not be in favor of certain technological advances would provide some very interesting discussion. These types of considerations would be beneficial to add to the use of this project in future classes.

Using the NAE's Grand Challenges for Engineering as the basis of the semester-long projects was quite effective. It provided some interesting topics that are current real-world issues being dealt with by engineers. It allowed the students to look at what engineers are doing, what challenges they face, and helps develop the professional skills that they will use in their future academic and professional careers.

## **Conclusions**

There was considerable positive feedback received through the survey of the students that participated in the Introduction to Engineering course project. The average ratings provided by the students about the project were on the positive side of the Likert scale (average ratings of 3.6/5 and higher). Areas were identified where some changes should be made to the project in future classes. The major focus for changes should be in the formation of the teams. Having the students provide some information about their schedules and interests in order to use the information to form teams could help alleviate some of the issues encountered with the teams. Having the teams prepare and sign a team contract outlining everyone's responsibilities and how they will deal with any problems may also be helpful in future classes. Also, providing the opportunity to each student to be graded on their individual contribution to the components of the project, in addition to grading the overall team's work would allow for each student to be accountable for their own grade rather than being able to have the other team members complete the work.

Using the NAE's Grand Challenges for Engineering as the topic of the semester-long project for the Introduction to Engineering course allowed for many of the ABET "professional" skills (3d, 3f-j) to be applied. The students were able to apply these skills while working on a project that presented many contemporary engineering issues.

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