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Introduction to Sub-Branches of Civil Engineering Fields through a Creative Freshmen Civil Engineering Design Course

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Please note that this paper has several co-authors as well.

Introduction to Sub-Branches of Civil Engineering through a Creative Freshmen Civil Engineering Design Course

Abstract

Freshmen students entering the Civil Engineering programs at some institutions are usually unaware of the numerous specialties within the field of Civil Engineering. They typically associate a Civil Engineering career with structural design. However, Structural design is only one of many components of the Civil Engineering discipline. Students are also unaware of the many interdisciplinary relationships that Civil Engineers address in order to accomplish their work.

Our campus has an aggressive local recruitment process, which results in a large number of students most of whom are first generation college bound students from local urban areas. These students grew up in neighborhoods surrounded by high-rise buildings. So naturally, these structures become a symbol of success, and many of them perceive the Civil Engineering field as predominately related to designing and building structures. Thus, one of the important objectives of the Freshmen Civil Engineering Design Course (Freshman Design Course) is to introduce students to various branches of Civil Engineering as it mirrors the Civil Engineering practice at large. The other most important objectives of the course are to develop the student's motivation, curiosity, and skills for continued learning and problem solving. The Freshmen Design Course provides the students with basic understanding of various branches within Civil Engineering and introduces them to what knowledge, skills, and attributes are required to be successful in later design courses so that they are well prepared when embarking on their senior design course.

Introduction

The Freshmen Design Course is designed to allow the students to explore their suitability for a career in Civil Engineering. Being a good fit for a Civil Engineering career is not just about academic or technical ability; it is also learning about preferences and enjoying the challenges that are presented by these preferences. By being exposed to the different disciplines and being exposed to practitioners, students can prepare to make educated assessments during their projects that help them to determine if a career in Civil Engineering is suitable for them.

Many students have difficulty in deciding on a Civil Engineering sub-discipline such as environmental, structural, geotechnical, transportation, or water resources engineering for a number of reasons. Many students may look for a direct match between a sub-discipline and career because they believe that a discipline sets their life path with little room to change. This is simply not true because most individuals have many career paths in their working lifetime regardless of the sub- discipline emphasized in their college education. This freshmen course describes different careers and options that an engineering degree will allow an individual to pursue.

In order to help decide on a branch, the students are encouraged to take the full listing of disciplines offered by the Civil Engineering school, and study them carefully. They are encouraged to explore these disciplines by talking to practitioners in the field, current majors in

the discipline of interest, faculty in those disciplines of interest, and to meet with professional advisors in the desired field. The students are also offered the opportunity to meet with visiting alumni practitioners in order to further explore their interests.

Finally, the students are encouraged to take courses in areas that appeal and motivate them, as well as take courses in topics that they are not familiar with to support their engineering careers. It is often found that students that take courses in areas they never planned on ended up helping them choose their specific discipline. This was done in the hope that when students are exposed to these diverse disciplines, they can expand their knowledge base which may lead them to consider multiple options when pursing their careers.

Methods

Pre-survey

The observation that students were less interested in disciplines other than structural engineering was noticed by a number of faculty at an early stage of their undergraduate studies. In order to validate this, a survey was administered in the Summer and Fall of 2014 to both the Civil Engineering Freshmen Design Course (mostly freshman students) and the Senior Design Course (senior students). The following questions were on the survey:

- When you first arrived to this campus, which of the following subfields in Civil Engineering disciplines were you most aware of?
- Why did you want to become an engineer?
- What is the most advanced math course that you have completed?
- Do you have an engineer in your family?
- When were you exposed to Civil Engineering?

The figures below indicate the freshmen student's to the survey. It is clear from the results that a majority of the students surveyed were mainly interested in structural engineering and indicated minimal understanding and/or knowledge of the other sub-fields within the Civil Engineering profession as shown in Figure A. In addition, most students became engineers because they liked the sciences or liked to construct things as shown in Figure B. Since many students are from first generation college families, they had limited opportunities to meet with other engineers, practitioners, or mentors. This was clearly represented as many students did not choose to become engineers because they were not influenced by a counselor, a friend who knew an engineer, or an engineer that was in their family as represented in both Figures B and C.

Civil Engineering Awareness before Course Work

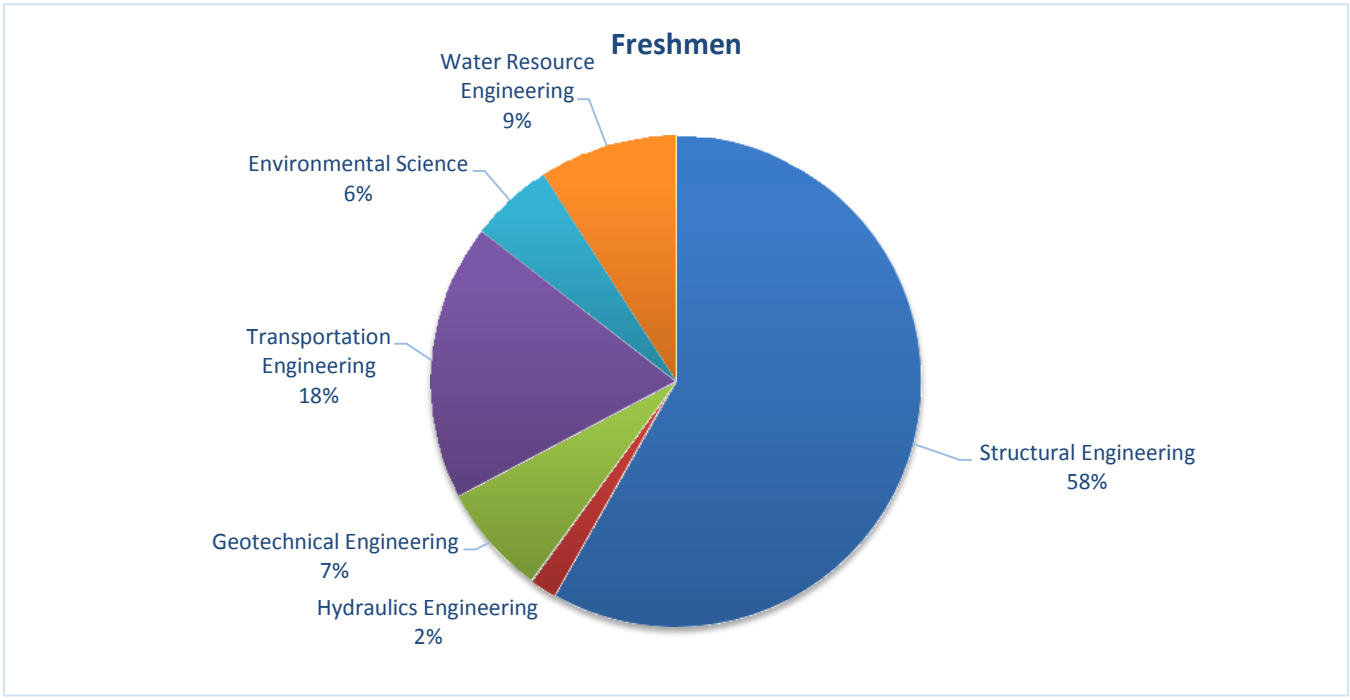


Figure A: Response Chart for "When you first arrived at college which of the following subfields in Civil Engineering were you most aware of?"

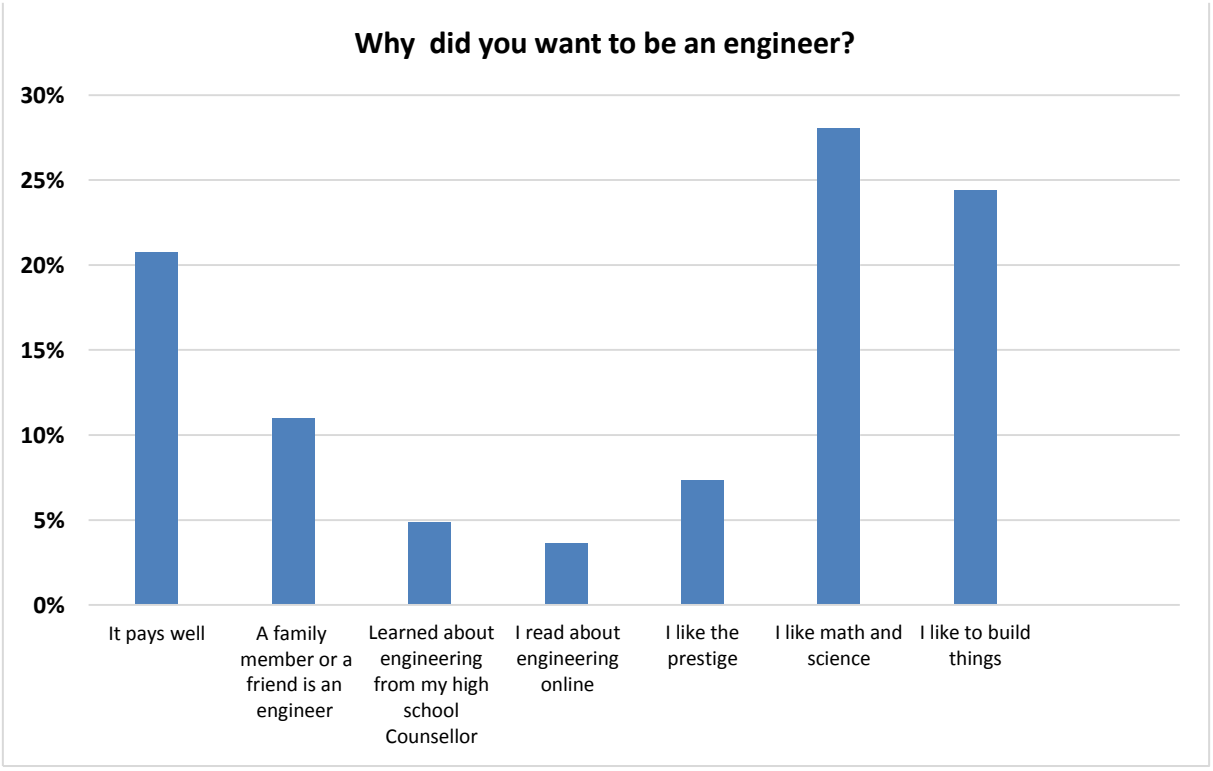


Figure B: Response Chart for "Why did you want to become an engineer?"

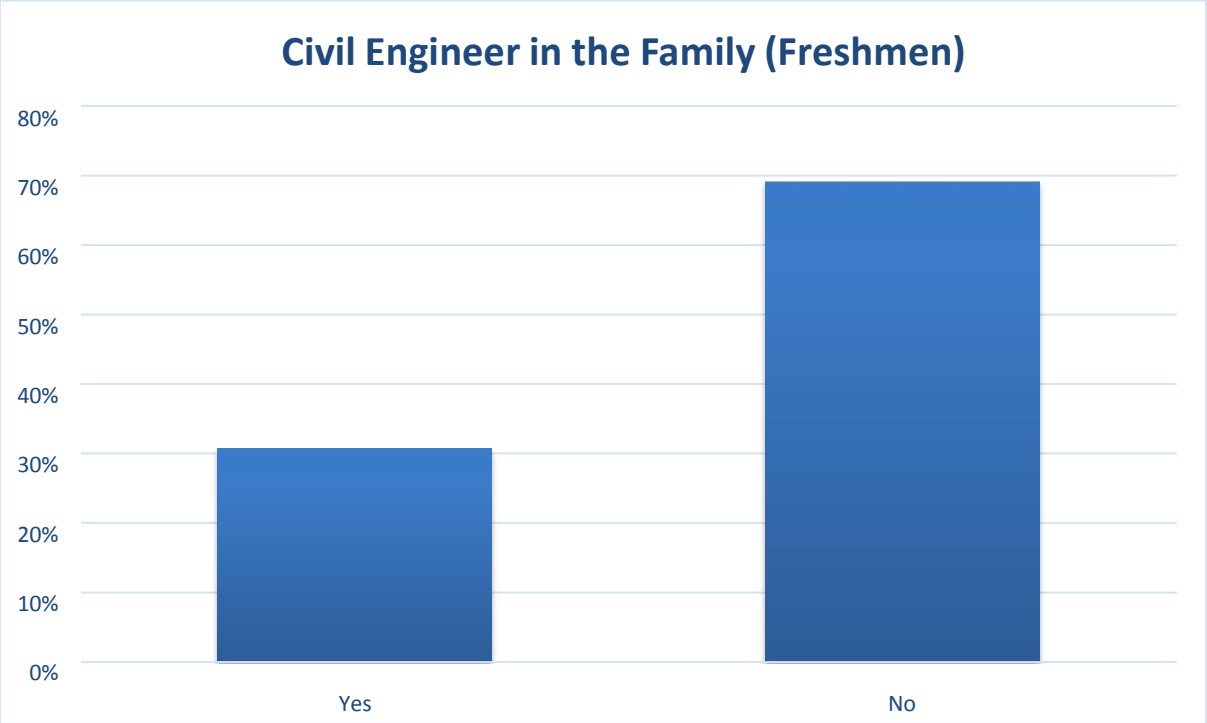


Figure C: Response Chart for "Do you have an engineer in your family?"

Exposure to the various Civil Engineering specialties or branches

Freshmen students entering the Civil Engineering program are usually unaware of the numerous specialties within the field of Civil Engineering. They typically associate a Civil Engineering career with the construction of buildings and bridges. However, this is a small component of what the Civil Engineering discipline entails. Students are also unaware of the many interdisciplinary relationships that Civil Engineers address in order to accomplish their work. Choosing the appropriate course work can place a lot of pressure on young students while they are trying to do well in college especially if they do not know what coursed to take to strengthen their engineering knowledge.

Developing engineering skills

Assessing a student's skills allows instructors to determine innovative methodologies to aid students in accomplishing their goals especially through appropriate coursework. Furthermore, exploring student's skills will allow them to match those skills to a potential sub discipline.

Exposure to the fundamentals of civil engineering

The Freshmen Design Course is designed to introduce freshmen students to the variety of Civil Engineering specialties that comprise the Civil Engineering field. In addition, the course is designed to equip the students with a basic knowledge of fundamental principles in order to prepare them to understand the importance of these Civil Engineering specialties. This early exposure in the Civil Engineering education to the variety of engineering specialties and to basic

fundamentals prepares the students to make knowledgeable decisions when selecting specialized courses as they complete their Civil Engineering degree.

The Freshmen Design Course is also designed to teach students how to become critical thinkers who are willing to ask the questions necessary to move closer to selecting the appropriate courses as they prepare for a career in Civil Engineering. As students spend time in the Freshmen Design Course, participate in its various activities, and interact with team members, they begin to develop critical thinking skills. This will allow them to pursue a potentially diverse and comprehensive educational experience that will help them develop the necessary skills for a career in Civil Engineering. Civil Engineering offers students many career options, the Freshmen Design Course gives them the tools to figure out what might be suitable to them.

The course projects

The course projects are designed to expose students to the theories, tools, and techniques of engineering design while promoting creative problem solving. The course also explicitly addresses several design cases involving problems that focus on the existing built environments, natural environment, economic and social factors, and expected life spans of civil infrastructure to identify, analyze, and discuss the importance of developing a diverse foundational knowledge in these fields.

Course structure

The Freshmen Civil Engineering design course meets four hours a day, twice a week for ten weeks in a quarter system. It has two hours of lecture and six hours of design lab per week. The course has prerequisites of Plane Surveying, Introduction to CAD, and Physics I. With this background, students are introduced to a practical Civil Engineering project where they can use basic knowledge of engineering principles to develop engineering design skills in multiple disciplines. The engineering design process[1] was presented in the following steps:

a) Define the problem
b) Gather pertinent information
c) Develop alternative solutions
d) Apply design constraints
e) Analyze each alternative using engineering skills and design constraints
f) Recommend the best solution

a) Define the problem

In 2012-2013, the students were required to perform preliminary design of a new water conveyance system and support facilities which included a dam, pump station, and pipeline that supplies water to a local community. The project required the design of a one-mile long pipeline that crosses an earthquake fault from a pump station at the base of a dam to a storage facility on a hilltop. Students were required to determine reservoir storage capacity, location, dam configuration and pipeline alignment based on the given constraints. In 2013-2014 students worked on the design of a dam facility and a roadway leading to the dam.

Transportation, geotechnical, structural, hydrologic, construction, environmental, and hydraulic consideration were discussed as part of the design project.

b) Gather pertinent information

For the water conveyance, the students were given a topographic map of the region. The students also researched applicable technical constraints such as site conditions and local geology as well as non-technical constraints. The students followed these constraints and incorporated them in their project design.

c) Develop alternative solutions

Each student team developed four alternative routes for the dam and pipeline system complete with plans, profiles, and cross sections. They later used these profiles and cross sections to determine the best alternative based on design constraints.

d) Application of design constraints

With this project, the students experienced early-on applications of ABET[2] design constraints such as economic, social, political, environmental, sustainability, and ethics in addition to the technical Civil Engineering design criteria and methodologies. They then critically evaluated each alternative under these constraints.

e) Recommendation of best alternative:

Once the student teams analyzed the alternatives with design constraints, they presented the alternatives and defended their choice during an oral presentation before a panel of professional engineers and industry affiliates. A list of advantages and disadvantages of the proposed solution, and a cost estimate for the construction of the project was presented.

Each course session began with specific topics to be applied in project design. The topics are summarized as follows:

1. Civil Engineering in today's world
2. Civil Engineering Specialty Fields
3. The Design Process
4. Contour Lines
5. Topographic Maps
6. Topographic Surveying
7. Introduction to water demand analysis
8. Introduction to water storage reservoir design
9. Horizontal and Vertical Alignments
10. Longitudinal Profiles
11. Cross Sections
12. Area and Volumes
13. Site Investigations
14. Design Constraints (Technical and non-technical)

15. Environmental Constraints
16. Introduction to Project Management
17. Quantity Take-offs and Cost Estimating
18. Introduction to Written Specifications
19. Introduction to Earthquake fault crossings

The students were required to implement elements of the above topics in the project's preliminary design. The drawings were prepared using MicroStation[3] CAD software. Samples from the student projects are shown in Figures 1, 2, and 3. During the design process, students are encouraged to share gained experience that resulted from errors and mistakes. Mistakes provide an opportunity for the participants to discuss and learn from each other. Recognizing the mistakes can effectively and positively reinforce engineering concepts. By reducing the number and time devoted to lectures and increasing the interactive problem based learning in a team environment, students learned more by applying engineering concepts to solve a practical problem. In order to provide students with exposure to academic research, they also participated along with upper class students in a seismic testing program where the performance of a ductile iron pipe was tested in the lab to simulate earthquake loads that demonstrated shear and bending failures. The course included a final group project report and a presentation before a panel of professional engineers and industry representatives.

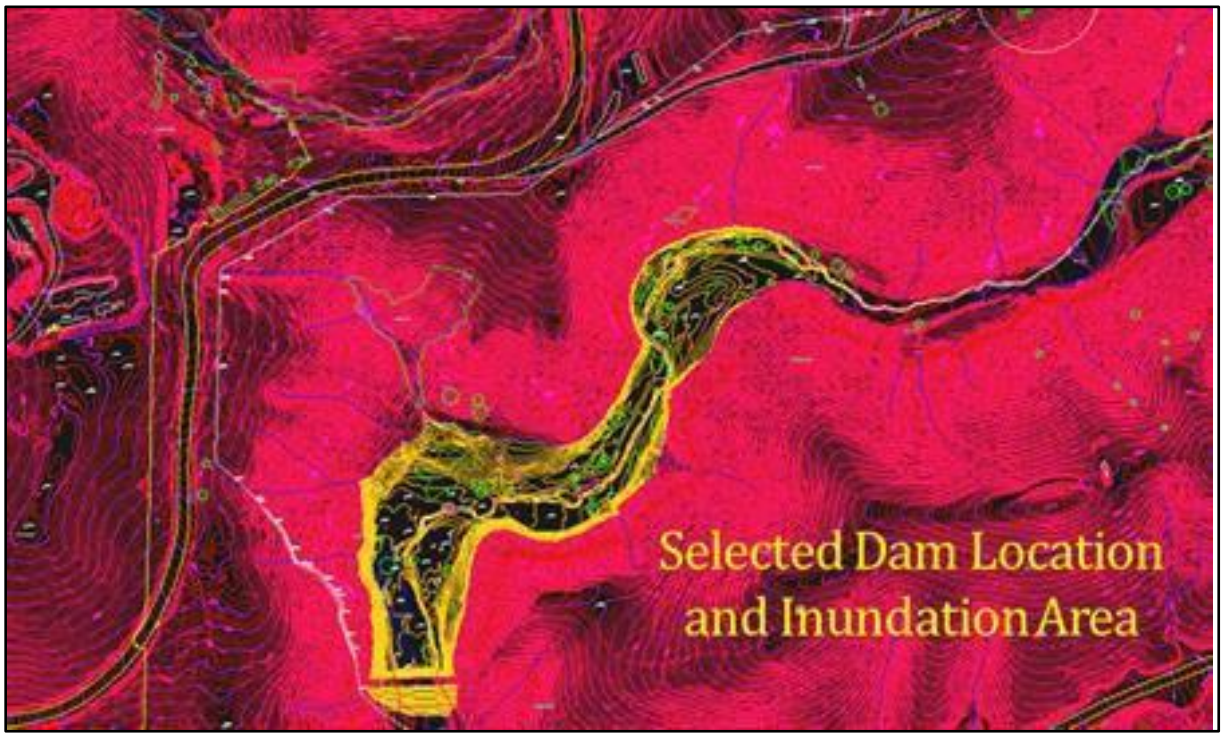


Figure 1: A Student Developed Dam Location and Inundation Area

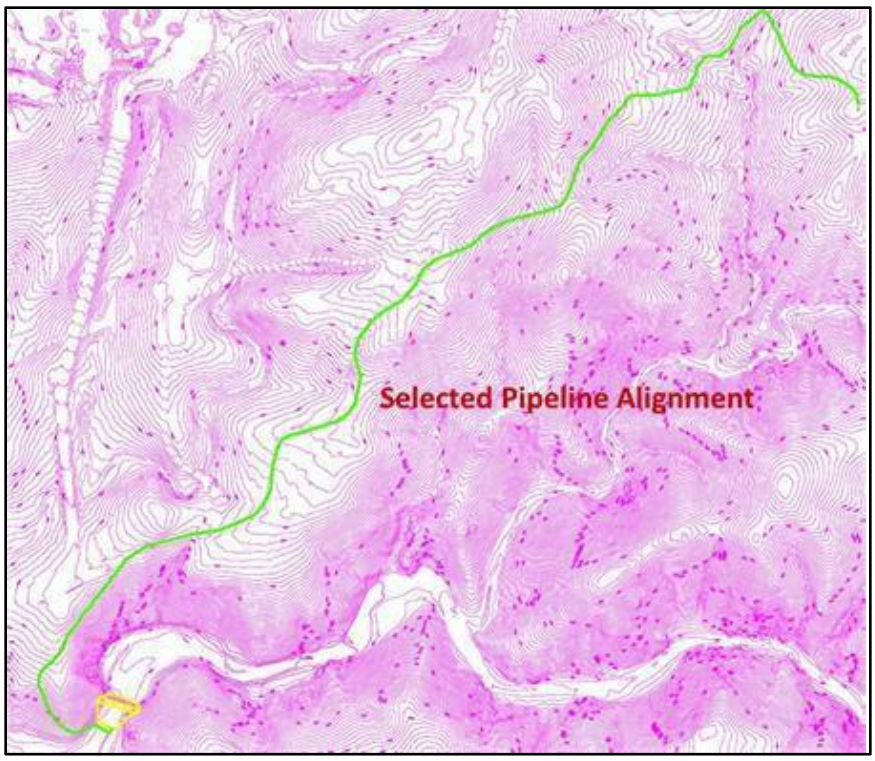


Figure 2: A Student Developed Pipeline Alignment

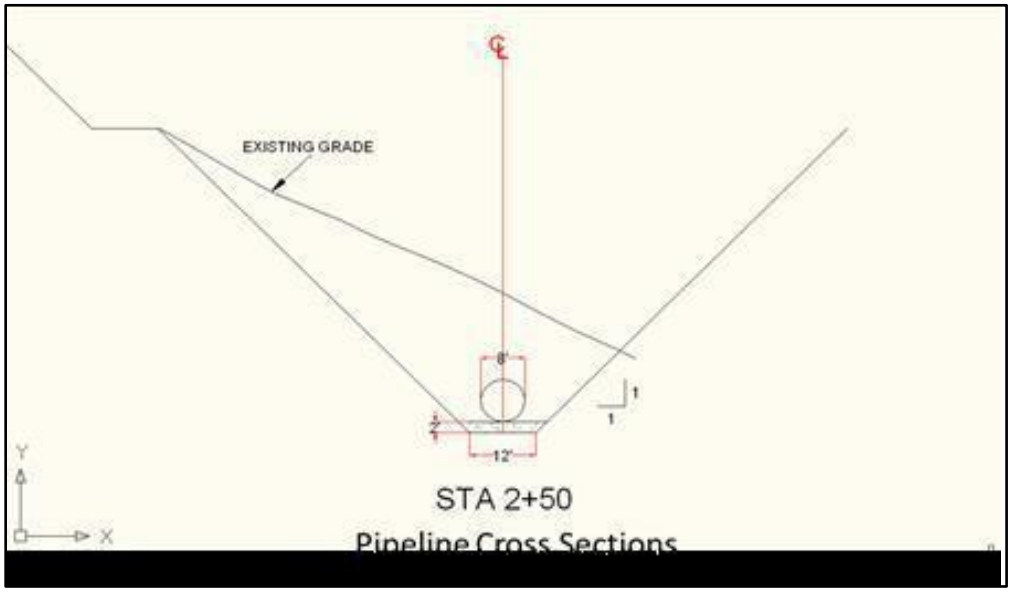


Figure 3: A Student Developed Pipe line Cross-section

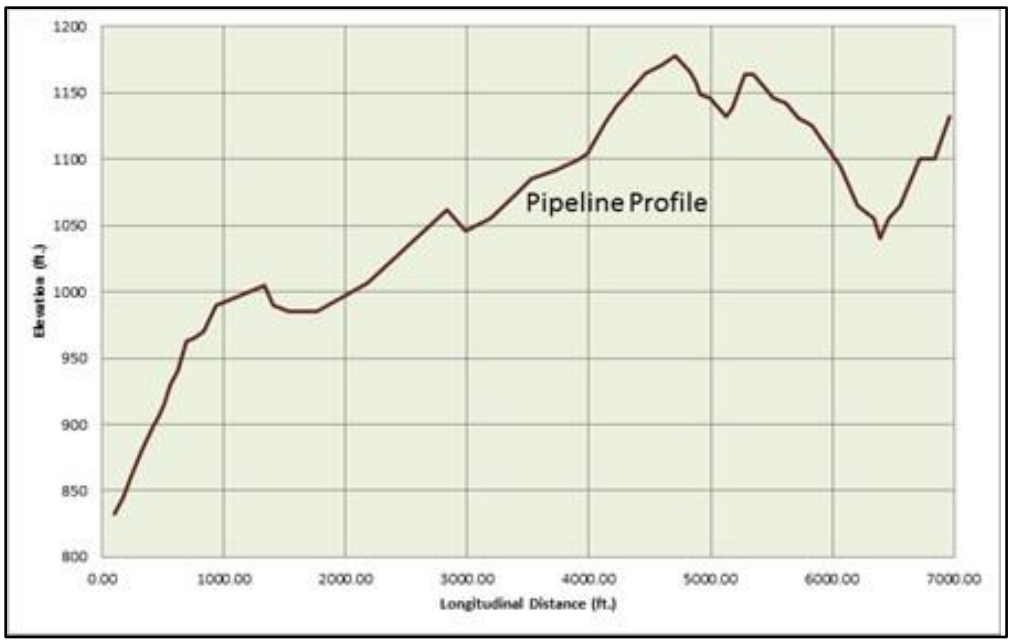
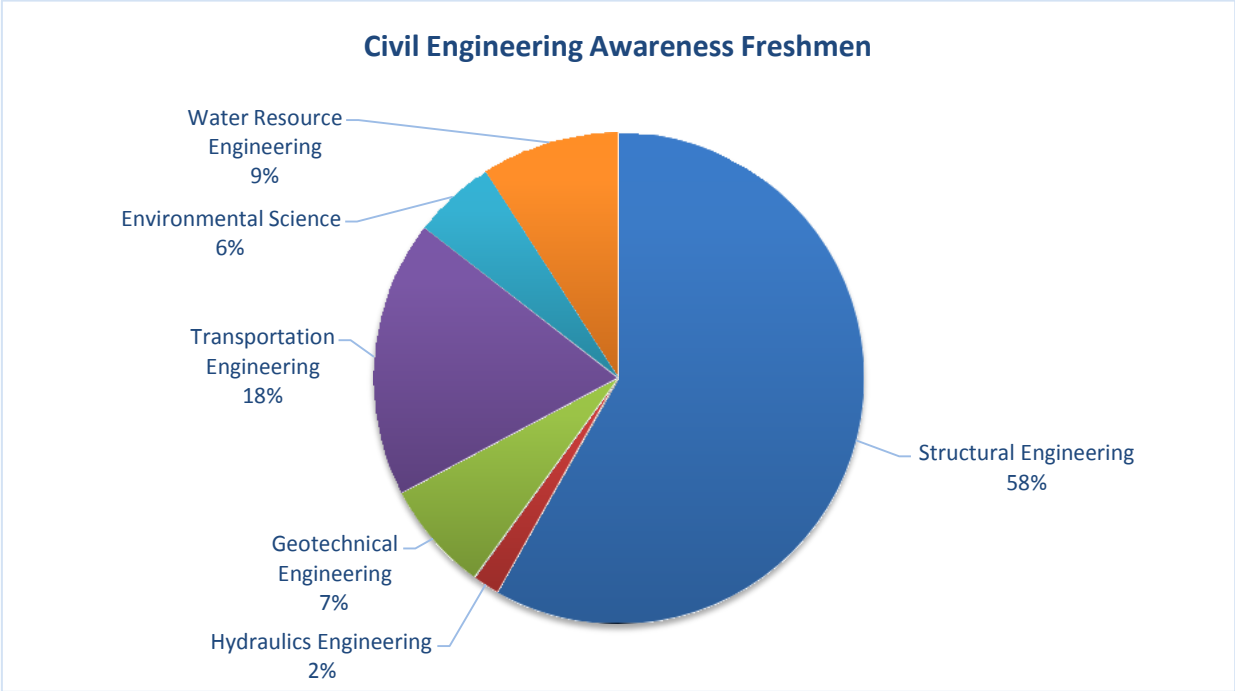


Figure 4: A Student Developed Pipeline Profile

The students were graded based on course attendance, project participation, teamwork, quizzes, a final examination, group project reports, and PowerPoint presentations. The individual quizzes and exams are based on lecture materials and design skills learned on the project.

Post Survey

A post survey was administered to students who have already taken the Freshmen Design Course and were currently taking the Senior Design Course (usually three years after the Freshman Design Course). In the Senior Design Course, students collaboratively worked on a Civil Engineering project where they must incorporate all sub-disciplines of Civil Engineering. All the prerequisites for the senior design course require students to take courses in at least four sub- disciplines of Civil Engineering. The introduction of Civil Engineering sub-disciplines in their Freshmen Design Course gives students an opportunity to better understand how their upper division courses affect their professional choices. In a follow up question, when the students were asked which of the Civil Engineering disciplines they are most aware of at that point in their student careers, the results show that students are interested in all branches of Civil Engineering when they are further in their education as shown in Figure D.



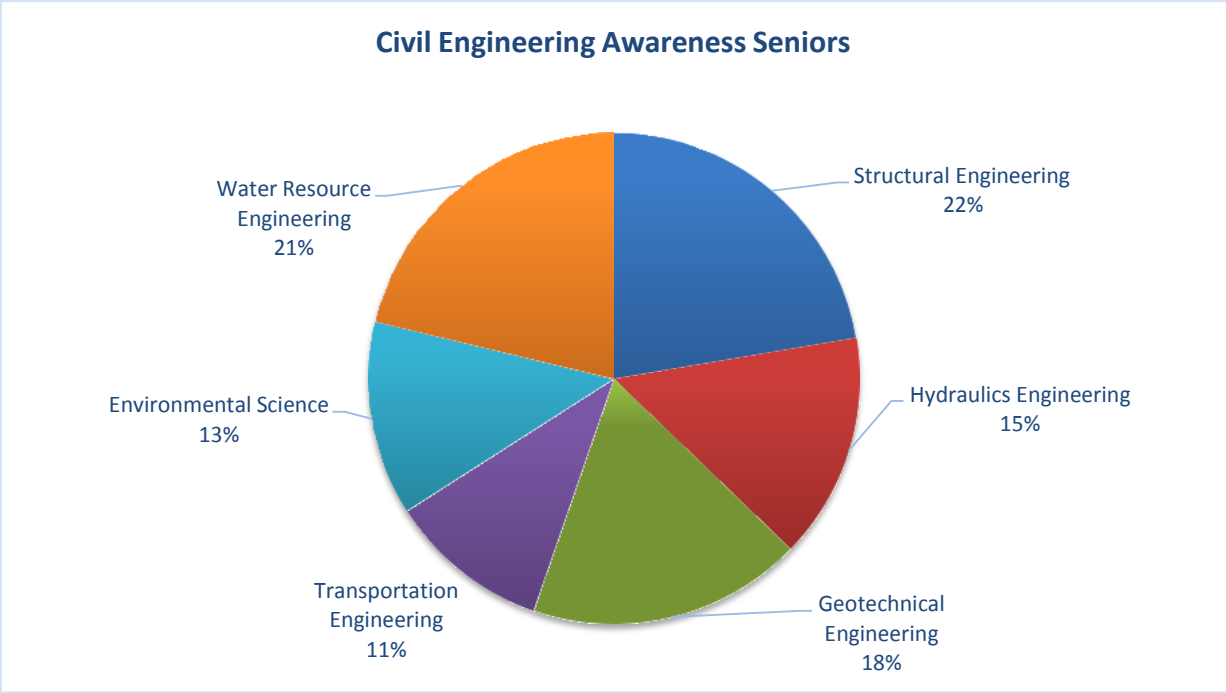


Figure D: Comparison of Civil Engineering awareness between freshmen and seniors

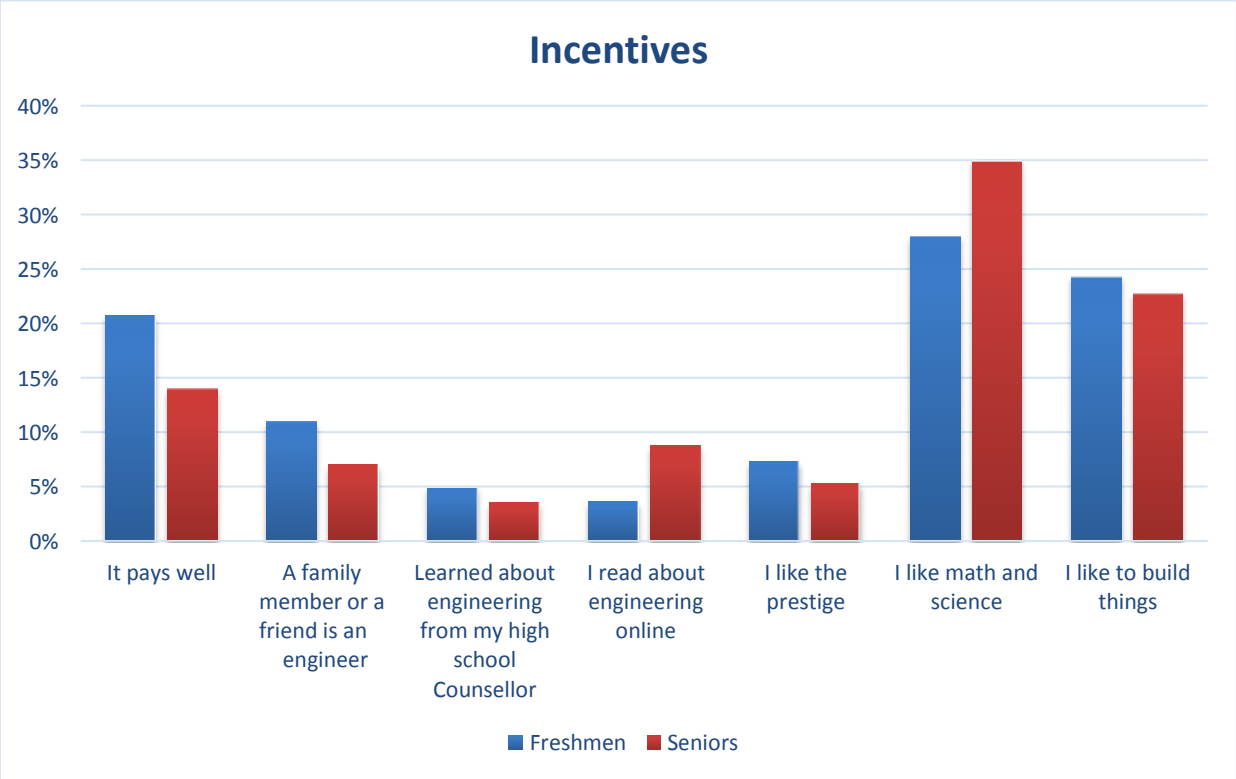


Figure E: Comparison Response Chart for "Why did you want to become an engineer?" between freshmen and seniors.

Conclusion

Freshmen students entering the Civil Engineering program at an urban campus usually reflect the makeup of the surrounding community of first generation college students with challenged economic backgrounds. These entering urban students had more exposure to the sub-field of Structural Engineering than any other branch of Civil Engineering. A Freshmen Design Course is utilized to expose incoming freshmen students to most of the disciplines within the Civil Engineering field. In-class projects that expose the students to various Civil Engineering disciplines is an important activity for first-year students, since it mirrors the way engineers, scientists, and mathematicians work in the world, and stimulates student's curiosity. The Freshmen Design Course provides the students with direction that gets the students involved in learning and increases their understanding for the need of a varied and diversified learning experience prior to graduation

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[2] Accreditation Board for Engineering and Technology, www.abet.org
[3] Bentley Systems, MicroStation CAD software, http://www.bentley.com/en-US/Products/microstation+product+line/