



## A First Year Course Based on Conceptual Design

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## **A First-Year Course Based on Conceptual Design**

### **Abstract**

The College of Engineering at the University of Utah includes many majors and departments. A great deal of effort has been placed on helping students choose a major prior to enrolling at the institution, but many students still enroll as undecided students. A course was designed to provide an engineering design experience to undecided students as well as students who are not academically prepared. The objectives of the course are to help students select a major in engineering, and to provide an early design experience to help them create realistic expectations for engineering as a potential profession. The university does not have a first-year program, therefore this course is important for helping students make an informed decision about which major in engineering is right for them.

This first-year engineering course is designed to demonstrate the interdisciplinary nature of engineering. Students are introduced to the design process and the grand challenges as outlined by the National Academy of Engineering. During the course of the semester, students begin to develop problem and needs statements. Those statements begin to take shape as they begin to identify marketing requirements, design specifications and begin the design process. Students are placed on interdisciplinary teams where they create innovative conceptual solutions to some of the grand challenges. The conceptual design project in the course has helped students realize where their interests lie. Furthermore, students begin to understand how their core coursework relates to both the design process and their future engineering courses.

In addition to conceptual design, students in the class are introduced to research happening within the College of Engineering through both tours of research facilities as well as faculty presentations. Additionally, there are four course mentors for the course, all of which are in their junior and senior years. These mentors help students select a major and consult on their design projects. The mentor relationship occurs at several points during the semester. During the first few weeks they come into the class to answer questions about why they chose their major, what they enjoy about their major and what they hope to do with their major. During subsequent classes, they give a short presentation outlining the context of the grand challenges discussed in the course, and then answer questions in a discussion format. As the semester progresses, they are paired with teams as mentors and provide feedback during the final grading of the design projects.

Student feedback was gathered after each semester, and changes were made to best meet student needs and interests. Feedback was provided in both qualitative and quantitative formats in the full paper, and demonstrated the effectiveness of the course in helping students choose a major, become familiar with the design process and create a better understanding of the engineering profession. This course has been taught for the past three years, and has been beneficial in helping many students choose a major, whether in engineering or not. Therefore,

this course has been effective for helping students gain exposure to engineering design and create realistic expectations for a major and a career in engineering.

## **Introduction**

Within the College of Engineering at the University of Utah, there are eight majors offered. While the retention rate of students in the program has not been low, there are barriers in place that do not allow for an easy transition between departments. Furthermore, other research universities across the US have implemented first-year engineering courses to help students gain a better understanding of engineering and design at an earlier point in their academic programs.<sup>1-9</sup> These universities have reported higher retention rates because not only have students gained more realistic expectations of engineering, but they have also gained both complex and critical thinking skills associated with engineering design. Because of these findings, a first-year course was developed which incorporated many of the teaching methods used at other universities.

The teaching methods outlined by other universities include hands-on projects,<sup>1-9</sup> which have been proven to increase motivation of first-year students. Just-in-time instruction, which presents curriculum material just as it is needed by the students, used in conjunction with team based learning and hands-on experimentation both in and out of class has also been proven as an effective learning and teaching strategy.<sup>9</sup> Other universities have utilized the consideration of context in design as a method for increasing learning.<sup>10</sup> This method demonstrated that women have a natural aptitude for contextual factors, while men have a greater learning curve. Many groups have demonstrated that team-based problem solving develops essential skills for engineering students, and one group illustrated that the design experience of students is positively affected by enhanced intellectual ability.<sup>4</sup> In all cases, it has been demonstrated that first-year engineering students benefit by incorporating hands-on activities, team-based project and design into first-year engineering courses.<sup>1-11</sup>

Other institutions have altered the teaching methods in the classroom to accommodate both the learning styles and the personality types of engineering students in order to increase the learning of those students, and consequently the retention of those students.<sup>12</sup> Institutions have demonstrated that taking rigorous courses prior to college enrollment increases retention; however, this is not frequently the case.<sup>12-18</sup> Furthermore, other universities have proven that incorporating learning communities increases student retention.<sup>19</sup> Therefore, by creating learning communities and adapting classroom teaching that considers the abilities of the students in the classroom, engineering students are better retained in engineering majors.

The problem at the University of Utah is that students were forced to choose a major during the first semester of their first year if they wanted to graduate in four years. Many students have enrolled with clear goals, and have graduated at a high rate; however, there is no mechanism to allow students to explore majors in engineering. Therefore, there needed to be a mechanism, which would allow students to explore engineering, while still gaining experience in engineering.

The structure of the institution in question did not permit for a first-year course to be taught with the rigor implemented at other institutions. Furthermore, the course was not

transferrable to many of the departments. Therefore a 0.5 credit hour course was designed to provide rigor and to give students an experience with the engineering design process. The course was designed to allow for exploration, but also to help students gain an understanding of engineering, so they could make an informed decision about whether they would pursue a major in engineering.

### **Course Description**

A first year engineering course was designed to give students an engineering experience. The course was designed to help students choose to major in engineering or to choose something else. If students chose to study engineering, one of the aims of the course is to help them choose which major will best help them meet their goals. To provide an engineering experience, students in the class were introduced to the engineering majors offered through the university. In addition, students were introduced to the grand challenges as outlined by the National Academy of Engineering as well as the interdisciplinary nature of engineering. Students were introduced to the design process, and faculty came into the class to talk about their research with two thoughts in mind. The first was to talk about the different kinds of engineers who work on the same research projects and to identify the role of each major. The second was to address how they use the design process in their research. Faculty interactions occurred both through lab tours and through classroom presentations. The final project for the course was to incorporate the design concepts discussed in class by designing a new technology that would help solve a small and focused piece of a grand challenge of their choice.

At the beginning of the semester, a presentation is given that addresses the majors in the College of Engineering, and students are assigned to bring at least three questions that they would ask an engineering student. During the next class meeting, engineering students, who are further along in their academic programs and are asked to serve as course mentors, are invited to the class to share their experiences. In this class meeting, the enrolled students meet with each course mentor in several rounds of “speed dating” where they take turns asking questions that are of interest to them. This has always been one of the most well-received class meetings of the semester because the course mentors have insights into the programs and their decision process that are not otherwise addressed in the course. After the “speed dating,” students are assigned to write a summary of what they learned.

During the semester, four weeks are devoted to in-class discussion of the grand challenges. The students are assigned to conduct research on each grand challenge prior to the class meeting and to come prepared with two things they learned and two things they would like to ask the class. One or two of the course mentors prepares a five-minute presentation that outlines the grand challenge. After the introductory presentation, the remainder of the class meeting is spent either discussing the grand challenge as a group or in smaller groups where students answer specific questions related to the grand challenge.

In addition to being introduced to the departments in the College of Engineering and to the grand challenges, students in the class learn about the engineering design process. This occurs throughout the course and within the context of the departments and challenges discussed in class. The final project is a conceptual design project where students work in small teams to identify a reasonable problem and need associated with a challenge of their choice. The students

create solutions to the problems and needs identified by designing prototypes and testing methods for demonstrating that their conceptual technology will function as planned. The project is not graded based on feasibility, but rather on creativity and following the design process.

## **Methods and Results**

During each year, the students in the class are asked to complete a course evaluation aside from the regular course evaluation procedures established by the institution. This evaluation was designed to assess the content of the course. Questions asked them to rank the classes for each week from favorite to least favorite and provide reasons for assigning both the highest and lowest rankings. Students were also asked if they changed their mind during the class, why they took the class, to identify factors that helped them make a decision, to rank the class meeting that was most useful to their learning style, what they liked most about their major, and to identify topics they would like to cover in class. The surveys were returned at a 90% response rate for each of the academic years. Of the students who provided responses, 73% were freshman in their first semester, with remaining responses coming from sophomores (21%), juniors (3%) and seniors (3%). In addition, there was a low percentage of women enrolled in the course, and the response from women was 22%, with 78% from men.

### **Fall 2011**

The format of the class was changed each year to accommodate the learning styles and formats of students. During the first year, the class was approved to incorporate the design process, but was not taught in that way due to political reasons within the departments. Therefore the course was taught by having representatives from each department come into the class to provide information on employment opportunities to the students enrolled in the class. The rank of the top class meetings (see Figure 1) revealed that the students enjoyed the professors who were more engaging and provided both demonstrations as well as time for questions from the students. Reasons why the students listed these meetings as their favorite included: interesting, informative, showed objects, and helpful in learning about major. The lowest ranked class meetings (see Figure 2) were from the professors who came in and presented without interaction. Reasons listed why students ranked these meetings lower include: too advanced, not related to chosen major and uninteresting.

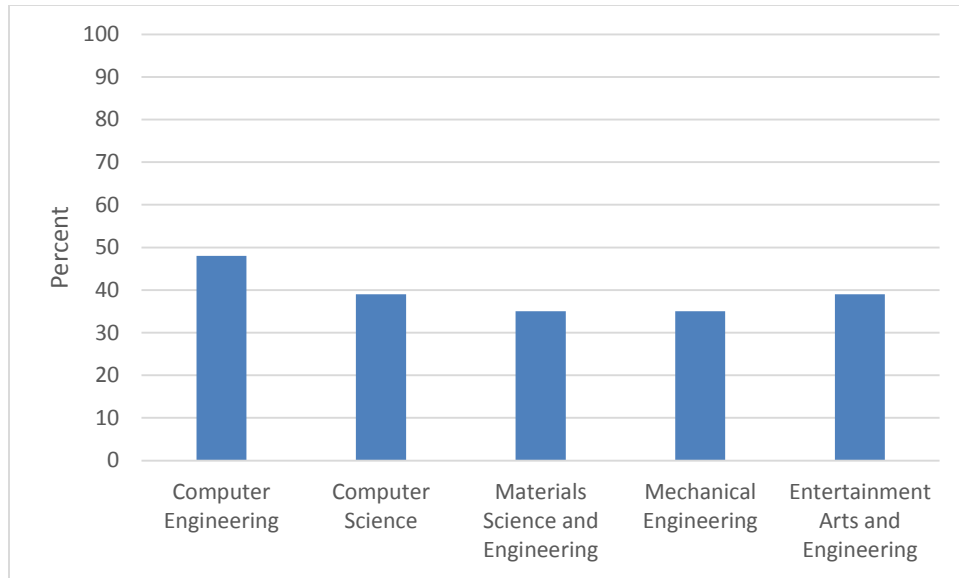


Figure 1. The top five class meetings for the semester reveal that students were interested in not only the content, but the delivery method. Those listed each incorporated a variety of teaching methods, including videos and demonstrations.

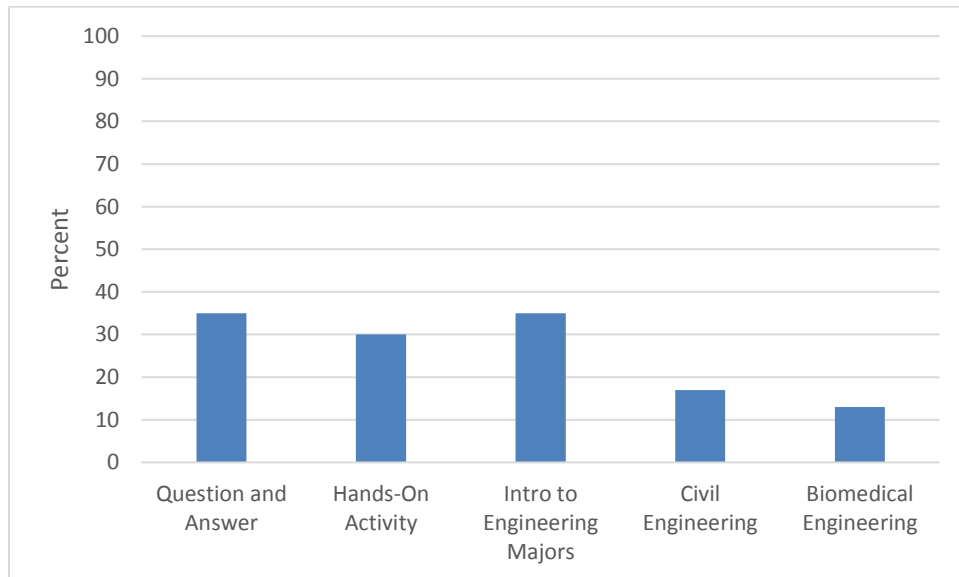


Figure 2. The five course meetings that received the lowest scores were surprising because three of the meetings listed incorporated a variety of teaching methods, while the other two were lectures by professors who lectured for the duration of the class.

Of students enrolled in the class 22% changed their major, and 7% were still undecided about their major. Students enrolled in the class for various reasons, but the main themes included learning about their major, interesting course topic, exploring majors in engineering, making a decision, and better understanding the majors within the College of Engineering. The factors that helped student choose a major are career opportunities in the major, salary and making improved technologies (see Figure 3).

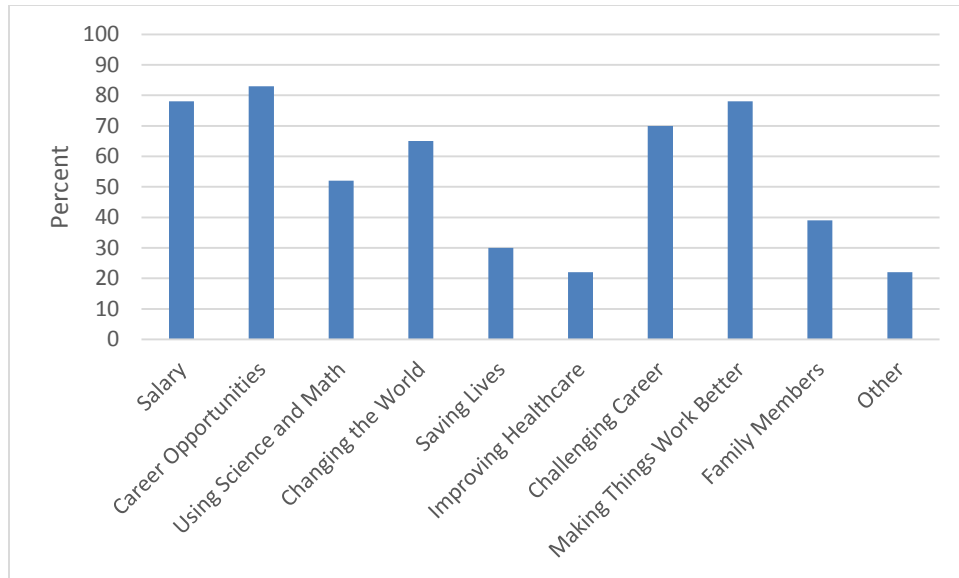


Figure 3. The students were asked to indicate (all that apply) the factors that may play the strongest role in choosing a college major.

When asked about the course format that would help them based on their learning preferences, students listed hands-on activities first, followed by tours of research facilities and lectures from professors (see Table 1). Students responded with similar themes when asked about what they liked most about their major, including math and science aptitude, research opportunities and the hands-on nature of engineering. The course topics that students would like to have addressed were including a segment on the daily life of engineers, research, the interdisciplinary nature of engineering, career opportunities more closely related to their chosen major, the application of engineering to life and the future career outlook for each engineering major. Questions were asked to determine the students' favorite components of the class, what they liked least about the class and what they would change about the class. With regard to their favorite parts, students indicated that hands-on activities, demonstrations and hearing from professors in the majors were the highest priorities. Students determined that boring lectures, grading based on attendance, low frequency of class meetings and unenthusiastic presenters were their least favorite components. When asked what they would change about the class, students said they would like to see lab tours, more hands-on activities, less redundancy with other courses and more engagement from guest lecturers.

Table 1. The students were asked to rank the type of classroom activities that would be most interesting for their learning style.

Rank	Learning Style
1	Hands-On Activities
2	Lab Tours
3	Lecture from Professors
4	Class Discussions about Engineering Challenges
5	Videos on Research
6	Lecture from a Single Instructor

Based on the data collected from student feedback, changes were made to the course format that included more of the learning formats that would better help them gain a better understanding of both engineering majors and engineering careers.

#### Fall 2012

The course format was changed for the second academic year based on student feedback. Because students listed hands-on activities, tours of research laboratories and classroom discussion as the top learning strategies, they were incorporated into the class. The class format was redesigned to focus on the grand challenges and include a final conceptual design project at the end of the semester. At specific points during the semester, students attended lab tours, engaged in hands-on engineering design activities and were introduced to various college success strategies. For the class meetings, four of the grand challenges were selected and presented for two weeks. Prior to the first class meeting, students completed an assignment where they researched the grand challenge and came to class with two things they learned and two questions they had about the topic. A course mentor, or group of mentors, came to class prepared with a five minute presentation about the grand challenge. A discussion was initiated after the presentation, which was based on the items the students had researched. Guest lecturers were brought into the class during the second week of the topic to talk about how their research contributes to solving the grand challenge in question. At the end of each topic, students wrote a reflection assignment addressing what they learned about each challenge.

Of students enrolled in the course, 26% changed their major, and 13% remained undecided. The course topics were ranked as in the previous year. The highest rated topics were lab tours and in-class discussions with course mentors and the instructor (See Figure 4). The reasons given for the high ranking include seeing the application of in class topics and the variability of the grand challenges. The least favorite class meetings were the guest lecture presentations and the final project presentations (see Figure 5). The reasons provided for the low scores included uninteresting topics and presenters who were not engaging. The students responded that the most influential factors in choosing a major were career opportunities first, followed by salary and the ability to change the world.



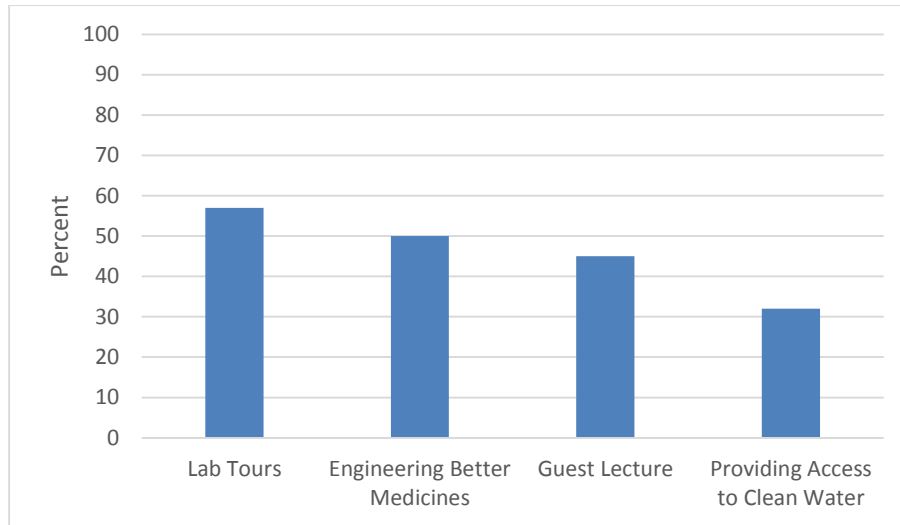


Figure 4. Students were asked to list their favorite class meetings. The top five are listed, but two of the top five were lab tours. In addition, two of the five are also sessions led by the course mentors.

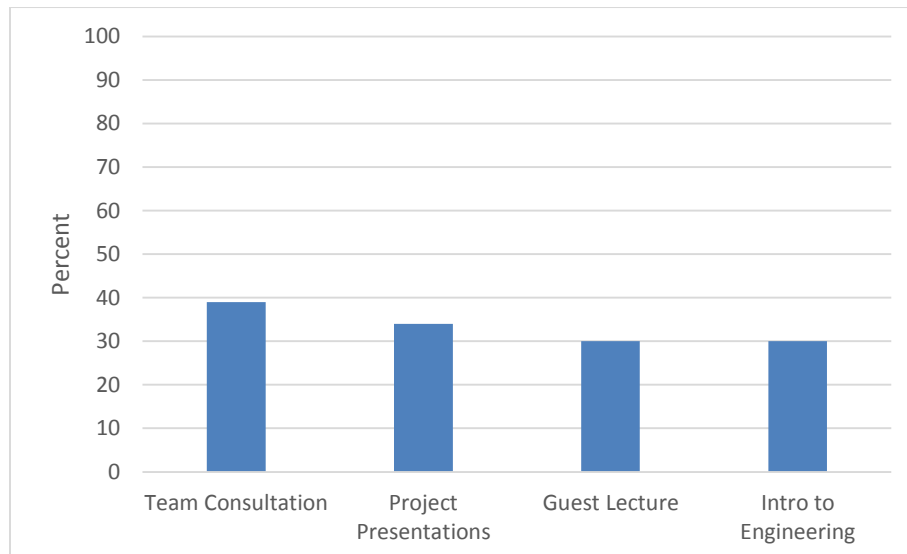


Figure 5. The course meetings shown here include the lowest ranked for the semester. There are also five listed here, with Project Presentations occupying two of the lowest slots.

Since the course offered in 2012 had a variety of formats, the same question was asked to students who had been introduced to course content from a variety of methods. The top results were the same as the previous year: tours of research facilities, hands-on activities and class discussions. One interesting note is that during the 2012 course, hands-on activities were incorporated into the course, but the overall rank was in the middle, and not listed among the top class meetings. When asked about what they like about their major, students responded with the versatility on the job, career opportunities, engineering falling within their interests and the ability to be creative. The favorite parts of the class were the in-class discussions and the lab tours, while the least favorite parts were the textbook selected and the homework assignments. In addition, when asked about what they would change about the class, students replied with

more hands-on activities, less time spent on the grand challenges and more time to work on the group projects.

The course was changed dramatically between the first and second years due to the student responses. While the responses were more positive during the second year, the course was modified to incorporate the components that the students would change, specifically more hands-on activities, less time on the grand challenges and more time to work on the group projects.

#### Fall 2013

The course was modified as specified above. The semester began with an overview of engineering, and then covered an introduction to learning styles and personality types. After the first few weeks, the students met the course mentors and had a “speed dating” session with them where they asked about how they chose their major and what they would have done differently. The design process was presented, and then the students were then introduced to the grand challenges. During the 2012 class, eight weeks were used to discuss and learn about the grand challenges, during the 2013 class, only four weeks were allotted. Condensing the time spent on the grand challenges increased the rigor of the course. Reflection assignments during this time were designed to assess their understanding of the grand challenges as well as to provide the application of the design process. Students learned how to translate the challenges into manageable problem and needs statements. Each week, the topic went slightly deeper. At the end of the semester, students were considering design elements and methods for testing them to ensure they met the needs statements. Students were placed into groups at midpoint of the semester, and were introduced to three hands-on activities where they explored different parts of the design process with their team members. In addition, lab tours were planned outside of class time, and resulted in a high attendance.

The majority of students enrolled for fall 2013 (78%) chose to major in engineering, while 11% remained undecided and 11% chose majors in other departments. Furthermore, 84% of students enrolled in the course said they enrolled in the course to learn more about the majors and to choose which engineering major was most interesting to them. The remaining students enrolled because the course was recommended by an academic advisor. Students responded that making things work better, career opportunities, changing the world, salary and using science and math were the main factors that help them choose a career (see Figure 6).

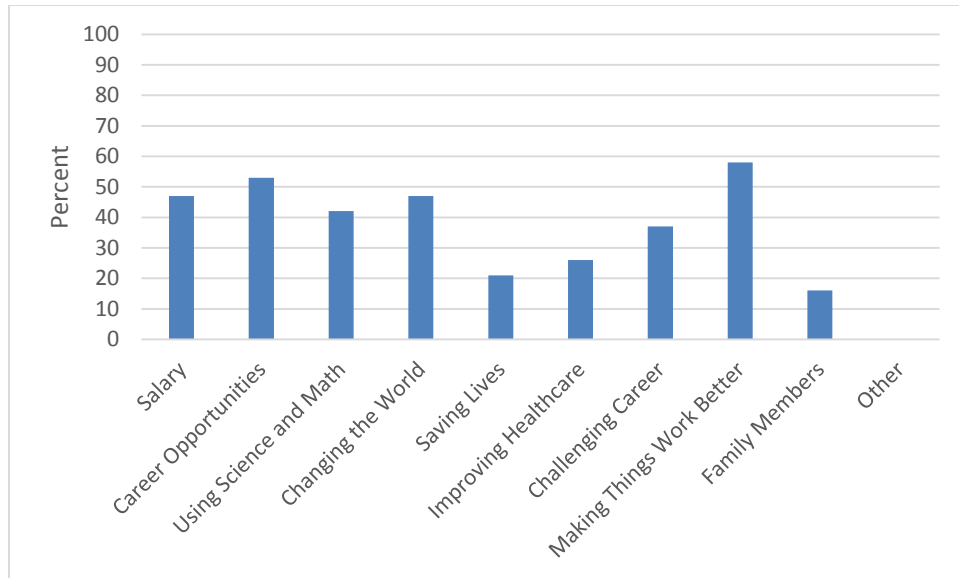


Figure 6. The students were asked to list (all that apply) the factors that were most influential in choosing a college major.

With regard to the course format, students enrolled in fall 2013 said that hands-on activities were most beneficial to their learning, followed closely by in-class discussions and lab tours (see Table 2). Students said that they like the ability to travel, make a difference, share scientific knowledge with the world, use math and science, and discover the world are the things that they like most about their majors. The course was taught differently during fall 2013, and students listed the following course topics as possible additions to in-class meetings: the day-to-day life of an engineer, what to expect after college and opportunities for graduate school. The majority of students were satisfied with the format and content and made no suggestions. When asked about their favorite part of the class, most students stated that they liked the discussions that illustrated how different engineers approach the same problem and the interdisciplinary nature of engineering. In addition, students liked learning about all of the kinds of engineering and assessing what they would like and dislike about each type, as well as touring research facilities. When asked about their least favorite parts, students listed personality types and learning styles, meeting only once per week and the stress of working in a group for the final project. Finally, students listed the following items as things they would change about the class: talking more about job opportunities and descriptions, and including more hands-on activities.

Table 2. The students were asked to rank the type of classroom activities that would be most interesting for their learning style.

Rank	Learning Style
1	Hands-On Activities
2	Class Discussions about Engineering Challenges
3	Lab Tours
4	Lecture from Professors
5	Lecture from a Single Instructor
6	Videos on Research

Overall students were much more satisfied with the course taught in fall 2013, and minor changes could be made to add more about the daily life of engineers and hands-on activities. These changes will be implemented for the spring 2014 course.

#### Retention of Students Enrolled in the Course

The enrollment records of the students who have taken the course were analyzed to determine the effects of the course on persistence in engineering majors as well as at the institution. Of students enrolled in the fall 2011 semester, 50% have been retained in engineering majors and 52% have been retained at the institution, but have chosen non-engineering majors (see Figure 7). Of students enrolled in the fall 2012 semester, 56% have been retained in engineering majors and 61% have been retained at the institution. For the fall 2013, it is too early to make a proper assessment about retention in engineering and at the institution, but currently 84% of students enrolled are enrolled in engineering coursework for spring semester, and with declared engineering majors. Furthermore, 100% of students enrolled in fall 2013 are currently enrolled in courses at the institution.

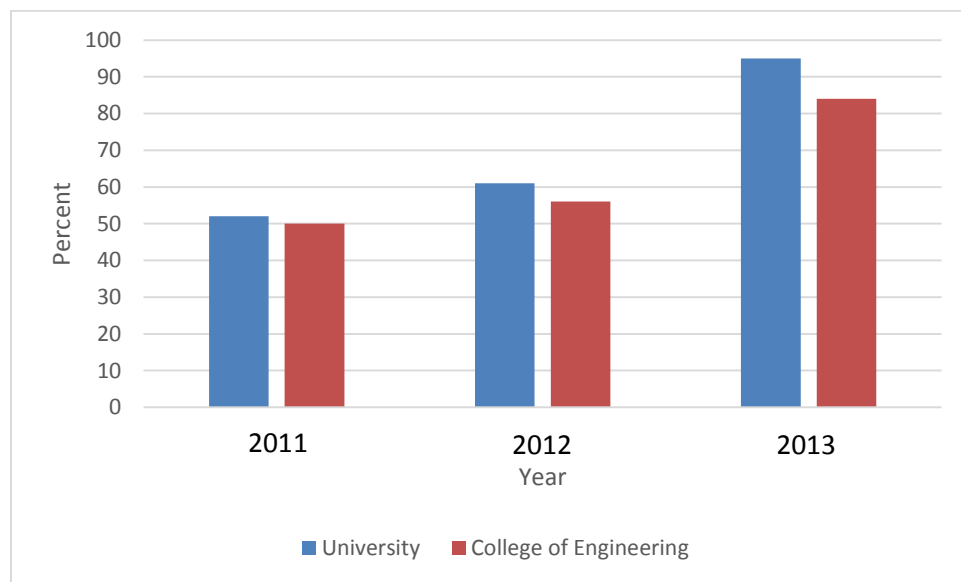


Figure 7. The percentage of students retained in the class varied by the teaching method used in course instruction. Year 1 represents the 2011 course, year 2 the 2012, and year 3 the 2013 course.

#### Conclusions

The first-year course taught in the College of Engineering at a research institution in the western US was designed to help students determine if they would like to major in engineering, and to help them choose which major is best for their interests and career goals. The course implements guest lectures, tours of research facilities, in-class discussions, team-based projects, and conceptual design as methods for teaching and learning that occurs both in and outside the classroom. The course was not taught in the way it was designed during the first year, and students were surveyed to determine the teaching methods they preferred for learning.

During the first year, students were retained at the lowest rate in engineering (50%). Students responded that they would prefer to have exposure hands-on activities, lab tours, and

lectures from professors during the course. However, when the course topics were ranked from their most favorite to their least favorite, the lowest ranked were included in their preferred teaching methods, including hands-on activities and lectures from professors. The course was modified the second year to incorporate a variety of teaching methods, including the addition of course mentors. Three of the top ranked class meetings included discussion about the grand challenges, and two of those three were sessions led by the course mentors. When the course mentors led the discussions, they presented the background of the grand challenge for the first part of the class, and then encouraged students to share what they had learned about the challenge prior to class or questions they had about the challenge. Questions were answered primarily by the instructor, but mentors were able to help as possible. The teaching methods used during the second year were continued with minor changes into the third year. Students were asked to rank their preferred learning methods, which differed from those preferred by students in the course taught during the first year. The top methods were hands-on activities, class discussions, and lab tours. The shift in learning preferences could be a result of many factors, including a different sampling of students as well as a better understanding from students regarding the learning involved through discussion of course material. During the third year, the discussions were much deeper than would normally be expected in a first year course because the students came to class prepared to discuss what they had learned.

As the course has evolved, student retention in engineering majors has increased. The majority of the students enrolled in the course during the fall semester of 2013 (84%) continued their enrollment in engineering programs. Furthermore, they stated that the course helped them choose a major or helped validate their decision to major in engineering. Furthermore, students enjoyed taking part in the design activity because it gave them a snapshot of what they could expect as they progress through their degree program. In addition to helping students choose to major in engineering, the content was modified to represent the preferred learning styles of the students enrolled in the course. As a result of this evolutionary process, the course has been able to adapt to meet the needs of enrolled students. This engineering exploration course with a design component serves as an example of how a university with structural challenges, that prevent the implementation of a first-year program, can adapt to help students explore engineering majors offered at respective institutions.

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