The Great Trebuchet Project

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Abstract
During Fall 2000, the Department of Civil and Environmental Engineering at The Citadel implemented a new version of its Introduction to Civil and Environmental Engineering course. The number of competitive team projects in the modified course was limited to two, so that the course could be designed to satisfy college-wide requirements for freshmen. While the two competitive team projects used in Fall 2000 were deemed satisfactory, the freshman committee decided to implement a new project in the Fall 2001 semester that it hoped would generate even more enthusiasm among freshman civil engineering students. This project is called “The Great Trebuchet Project”. This paper describes the Great Trebuchet Project and the involvement of the freshman and junior classes. In addition, the paper provides a student assessment of the project. Results of the paper may be of interest to those who are seeking ways to improve courses of a similar nature.

Introduction
What engineering professor wouldn’t want to create a course module that would grab students’ attention, improve participation and involvement, be fun and intriguing enough to generate enthusiasm, teach them that engineering is more than just a single-problem event, and teach them to work in a team-based environment where each person contributes to the solution but no one person is responsible for all aspects of the problem-solving process? Over the years, the Department of Civil and Environmental Engineering at The Citadel has gradually refined its Introduction to Civil and Environmental course with the goal of creating such modules. The department was at least partly motivated to make these modifications in an effort to improve retention between the freshman and sophomore years. The result has been what the department feels is a well-balanced course containing a variety of modules that not only introduces students to civil and environmental engineering, but also creates academic growth opportunities and potentially generates enthusiasm for the engineering profession.

Based on experience extending over a decade, the department discovered that team-based competitive projects were the most successful modules in generating enthusiasm among the students taking the course. Although the department’s original plans were to increase the number of these type projects in the course, creation of an institution-wide course for all freshman students has contributed to limiting the number of these projects to two for a semester course. While the two projects offered in 2000 – 2001 were deemed to be effective, the department decided to replace one of the projects with one that could potentially generate even more enthusiasm while at the same time providing an opportunity to involve juniors in one aspect of the project. This project is called “The Great Trebuchet Project.”

The purpose of this paper is to describe the Great Trebuchet Project and the involvement of the freshman and junior classes. In addition, the paper provides a student assessment of the project.

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**Background**

*Projects and Hands-on Activities in Freshman Engineering Courses*

In sharp contrast to many engineering curricula available several decades ago, schools are now creating energetic learning experiences for freshmen that immediately give them a “feel” for what it is like to be an engineer with a challenging assignment. One way to do this is to offer mini courses on technology that capture real-world examples in a setting that can be understood by first-year students. Commenting on such courses in a recent Prism article, Ioannis Miaoulis, dean of the Tufts University College of Engineering, pointed out that “These courses make engineering very exciting and bring it closer to everyday life.”

Another way of creating real-life engineering experiences for freshmen is to incorporate design projects or other hands-on activities as part of a course. Depending on course goals, such activities can provide a number of valuable outcomes. For example, projects can effectively introduce freshmen to the world of engineering, whether it is general knowledge or related to a specific curriculum. Theoretical concepts from lectures can be brought to life through implementation of a project or activity.

Many projects require students to work in teams. Learning about team dynamics and developing interpersonal skills are among the many benefits that can be derived from participating on projects. By working with other students on a project, long-term bonds among the participants can be forged. Students often discover that teamwork can be a powerful resource in creatively solving problems – particularly when a multidisciplinary approach is used.

Perhaps an unexpected benefit from working on projects is the potential to improve communication skills. When written reports or writing assignments are required, writing skills can be enhanced. Presentations help to improve oral communication skills. Some projects are designed to promote student contact with clients and outside experts. This type of contact will no doubt be invaluable to students when they enter the workforce. Project defenses or peer reviews can help prepare students for similar situations in their future jobs.

Finally, when student attitudes about engineering soar, retention is likely to be higher. Because projects and hands-on activities can be fun, rewarding, and intriguing for students, enrollment can be positively impacted.

A cross-section from the recent literature of projects incorporated into freshman engineering courses is provided in Table 1. While not all-inclusive, the list of selected works illustrates both the variety of projects that have been developed specifically for first year students and the benefits discussed above.
Projects and Hands-on Activities in Introduction to Civil and Environmental Engineering

In the late 1980s, the Civil Engineering Department established a new course for freshmen called Engineering Design and Analysis. To emphasize hands-on activities, a laboratory format was adopted for the course, which held two-hour classes twice a week. Later the course was renamed Introduction to Civil and Environmental Engineering. In addition to topics such as introduction to engineering, engineering fields, areas of civil engineering, the design process, professionalism and ethics, fundamentals of problem solving, and basic computer applications such as spreadsheets, a number of civil engineering mini projects were included in the course. Most of the mini projects were designed to be completed in a single two-hour session, although a few of the mini projects were longer.

Among the reasons for creating the course were to motivate students and improve retention by giving students a “feel” for performing engineering work. It was felt that the visual, hands-on projects could help achieve this.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
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| 2         | Design Lighter-Than-Air vehicles – blimps up to 5 feet long  
Competition: Blimps flown around basketball court (carry most weight in minimum time) |
| 3         | Design of new cart to transport equipment from storage building to athletic field |
| 4         | Fictitious murder solved using nuclear techniques; involves role play and subpoenaing of expert “witnesses” (instructor and other faculty) |
| 5         | Design electromechanical device to deposit ping-pong balls in 18-inch high Nerf basketball hoop, 8 ft away; team competition included |
| 6         | Design, build, and program a “smart” car complete with light and touch sensors using LEGO Robotics Kit; competition involves maneuvering car through an obstacle course |
| 7         | Different projects each semester to promote creativity; e.g., competition: most “nuts” (ping-pong balls attached to a wooden dowel tree with Velcro) picked by two competing nut-pickers |
| 8         | Students from two disciplines construct a LEGO vehicle complete with sensors, lights, and actuators; Competition: chase scenario; one car acts as “prey” and the other as “predator” |
| 9         | Design, construct, and test a solar water heater |
| 10        | Design, evaluate, and race edible cars |
| 11        | Reverse engineering integrated with design graphics project |
| 12        | Design and construct handicap access for buildings at a historic site |
| 13        | Design and construct steam-powered generator and steam-powered car  
Competition: most efficient car (longest distance, least fuel) |

Table 1. Projects in Freshman Engineering Courses
As the course progressed, a number of refinements were made to enhance the active learning elements of the course. Nonetheless, because of significant attrition rates, the department decided in the late 1990s to establish a committee to study what could be done to improve the freshman year, including the Introduction to Civil and Environmental Engineering Course. The committee discovered that in general students were very satisfied with the course, particularly the active learning portions of the course. However, there were some course elements that were not as effective, and the committee identified these as elements for change.

Ultimately, the committee identified a mini project called the “office layout project” as a highly successful project that could be used as a model for other projects. A number of other projects were proposed based on the office layout project model. Included in the model were the following components: work in teams of 2 – 4 students, in-class review and discussion of specific project evaluation criteria, oral and written presentation of work, peer evaluation of team performance, and announcement of competition results with recognition of winners.

The school established a new course (called Citadel 101) that was required of all college freshmen for Fall 2000. Therefore, after teaching the newly modified course for only one year, the Civil and Environmental Engineering (CEE) faculty found it necessary to again modify Introduction to Civil and Environmental Engineering to accommodate the goals associated with Citadel 101. Since many of those goals were already being addressed in the existing Introduction to Civil and Environmental Engineering course, the changes required were not substantial. However, there were enough changes to limit the number of competitive team projects to two.

In Fall 2000, the competitive team projects used were the office layout project discussed above and another a parking lot design project. While these were quite successful, the committee decided to make some changes that it hoped would generate even more enthusiasm among the students. One change was using an actual project underway in the Charleston area during Fall 2001 for the basis of the office layout project. After teams had submitted their proposals, they were shown the same project performed by an engineer.

The other change was to replace the parking lot design with “The Great Trebuchet Project.” Details of the trebuchet project will be discussed in the next section. A more thorough discussion of the modifications made in the Introduction to Civil and Environmental Engineering course is available.

The Great Trebuchet Project

A trebuchet is a historic war engine used in siege operations as early as the thirteenth century. Working on a counterweight principle, some of the historic trebuchets were reported to hurl 300-pound boulders up to 200 - 300 yards.

The overall concept of the “Great Trebuchet Project” was to construct a model trebuchet and use it in a competition where teams would try to hit a target by aligning the trebuchet, selecting the appropriate counterweight, and “shooting” at the target. Although one of the authors (Stout) had previously constructed a model trebuchet, it was too small for purposes of this project and it was necessary to construct another.

To ensure that the model trebuchet would be ready by the date of the competition, it was decided to order a trebuchet kit from Trebuchet.com. The model is a 1/10 scale wooden model of a historic trebuchet called the “Warwolf”. With the 4 foot arm extending vertically, the model is about 51/2 feet high. Along with the trebuchet kit, two sizes of metal projectiles were ordered: approximately one-half pound (1-1/2 inch diameter) and one pound (2 inch diameter). A photograph of the completed trebuchet in launching position is shown in Figure 1.
During the early part of the semester, both faculty and students worked on assembly of the model trebuchet. Work periods were typically less than an hour. Given the time for glue to dry and the cut-and-fit nature of the assembly, only a few students were needed for a given work session. To build enthusiasm for the project, a PBS documentary on trebuchets was shown to the students before the construction process began (NOVA, “Secrets of Lost Empires: Medieval Siege”). The film did an excellent job of explaining the scientific principles associated with the operation of the trebuchet.

Counterweights were made by measuring out one ten-pound bag of sand and a number of one- and two-pound plastic bags of BBs. This enabled counterweight to be evenly distributed in the bucket and easily adjusted between shots.

The project was conducted on two separate days. On the first day, data was taken for the distance the two-pound projectile traveled as a function of counterweight added to the bucket. A number of measurements were taken for counterweights ranging between 18 pounds and 32 pounds. A minimum of three measurements was taken for each counterweight.

Following data collection on the first day, student teams were instructed to create plots of counterweight versus projectile distance to aid them in predicting how much counterweight would be needed to hit a target randomly placed at some distance from the trebuchet. Teams brought their graphs with them to the competition held at the next class period. Some teams determined a best-fit equation (based on material they had learned during the semester) and brought calculators to help determine the counterweight.

For the competition, a plastic bucket was placed randomly somewhere on the field within the range of the trebuchet. Teams were given three shots at the target. After each shot, teams were allowed to adjust the counterweight and alignment of the trebuchet before making the next shot. Winners were selected on the basis of the shortest average distance from the target.

To promote safety, only a faculty member loaded the projectile into the trebuchet. All students were required to stand well clear and to the sides of the trebuchet. No one was permitted either in front or back.

In the initial planning for the “trebuchet project”, it was hoped to involve students from the junior class enrolled in CIVL 330 - Measurements, Analysis and Modeling for Civil and Environmental Engineering with some related activities of the freshmen course. Unfortunately, this did not take place because of scheduling problems. The military environment at The Citadel places very high demands on the students’ time and does not give much opportunity for “cross-class” interchange during the normal academic day. CIVL 330 students assisted in the construction of the trebuchet. The trebuchet also served as the focus of an assignment, in which the CIVL
330 students were to develop a mathematical model that would predict the position of a projectile. The model incorporated uncertainty of the launch parameters and lead the students to generate an estimate of both the nominal position of the particle and the uncertainty of the position at some time during the flight. This was a very eye-opening exercise for the students; they were amazed by the effect of the slight uncertainties of the initial conditions on the position of the particle during its flight. The juniors’ involvement with the trebuchet extended to a take-home question on the CIVL 330 final examination requiring them to: “Discuss how you would develop from the concepts of this course, a means of predicting the range of the projectile thrown by a large trebuchet given the small model available in the department.” The submissions were interesting, including some obvious and some quite creative suggestions. The proposals described plans to conduct field trials with the model to gather data, use the Buckingham Pi Theorem to develop scale relationships to extend model performance to the larger trebuchet, and to identify the functional relationships in the system. Some students even suggested developing Monte Carlo simulations of the systems. In the end, several students have asked about developing senior research projects from questions and ideas that arose during the trebuchet assignments.

**Assessment**

At the end of the semester, students were asked to assess the course through a survey administered in the CEE computer laboratory. Two of the sections could not complete the survey because a visit by the President of the United States preempted the time period scheduled for the survey. It was not feasible to reschedule the assessment for those sections since final examinations began the next day. Approximately 51 percent of the students, or 32 of the 63 students enrolled, completed the survey. The survey was three pages long and took 10 to 15 minutes to complete. Anyone interested in obtaining information about the survey should contact one of the authors.

When plans for the trebuchet project were made, it was hoped that the project would help to generate even more enthusiasm for Civil Engineering than had been noted in the past. Results from the survey indicate that the trebuchet project did indeed help to raise the level of enthusiasm. One of the questions on the survey asked “What was the most enjoyable subject or activity in the course?” Sixty-nine percent of the written responses to the question mentioned the trebuchet project. Another 16% mentioned the office design project, the activity that had been judged to be the most popular activity in previous years since it was incorporated into the course in the early 1990s.

Furthermore, when asked what effect various topics from the course had on their interest in Civil Engineering (i.e., whether a topic raised, lowered, or did not change their interest), 84 percent of the respondents said that the trebuchet project raised their interest. Compared to the other topics in the course, the trebuchet project was identified as the topic that raised the interest of the largest percentage of the students surveyed. Working with engineering drawings ranked second (81 percent) and the office design project ranked third (78 percent). An overwhelming percentage of students (97 percent) preferred hands-on learning activities such as the trebuchet project as opposed to traditional lectures. Eighty-two percent felt that team-based activities in the course had helped them learn about Civil and Environmental Engineering. The survey questions for hands-on and team-based activities are similar to the results obtained during Fall 2000. Most of the students (91 percent) said that a competitive aspect enhances projects such as the trebuchet or office layout.

One set of questions on the survey focused on the general level of interest and understanding about CEE as an academic major and profession. These questions and their responses are summarized in Table 2. Responses for both Fall 2001 (with the trebuchet project) and Fall 2000 (without the trebuchet project) are listed in the table. It should be noted that other than the trebuchet project, there were no substantial differences between the Fall 2000 and Fall 2001 courses. The professors were the same, the same classrooms were used, and the ratio of female to male respondents was the same. Almost 70 percent of the students felt that the course raised their interest in Civil and Environmental Engineering and 100 percent of the students surveyed felt that the course was either moderately (47 percent) or very successful (53 percent) in teaching them about civil engineering. A
comparison of the student responses for the first two questions in Table 2 from the Fall 2000 and Fall 2001 surveys failed to show a difference at the 5 percent level of significance.

Almost 60 percent of the students said that what they had learned in this course convinced them to stay in CEE, compared to 47 percent in Fall 2000. This difference was not significant at the 5 percent level, nor was there a significant difference in the percentages of students responding that the course convinced them to change majors. There was a significant difference in the other two columns ("did not alter thinking about CEE" or "left me unsure"). However, the "left me unsure" percentage in Fall 2000 represented write-in responses. Because of the write-in response in Fall 2000, the "left me unsure" selection was added to the Fall 2001 survey. For this reason, it may be difficult to statistically compare the survey results associated with Question 3.

With regard to retention, over 70 percent of the students expressed their intention to remain in CEE. These differences were similar to the excellent results of the previous year and the differences were not found to be significant at the 5 percent level. As noted above for Question 3, the "left me unsure" percentage on Question 4 represented write-in responses in Fall 2000 and the selection was added in Fall 2001. Therefore it may be difficult to statistically compare the results from the two years on Question 4. It is also interesting to note that of those who were planning to change majors, all but one of the responses identified "math" as the reason; the other listed "grades" as the reason. Interestingly, half of those who were planning to change majors responded that math was their hardest topic in this course, and the other half listed another topic. While 22 percent of all the responses listed math as the most difficult concept in the course, 81 percent said that the mathematics, trigonometry, unit conversion, problem solving, and calculator exercises were beneficial in areas other than CEE.

<table>
<thead>
<tr>
<th>Has CIVL 102 affected your interest in CEE?</th>
<th>Raised</th>
<th>No change</th>
<th>Lowered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2001</td>
<td>69%</td>
<td>28%</td>
<td>3%</td>
</tr>
<tr>
<td>Fall 2000</td>
<td>61%</td>
<td>24%</td>
<td>15%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How successful was the course in teaching you about civil engineering?</th>
<th>Very</th>
<th>Moderately</th>
<th>Not very</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2001</td>
<td>53%</td>
<td>47%</td>
<td>0%</td>
</tr>
<tr>
<td>Fall 2000</td>
<td>61%</td>
<td>30%</td>
<td>9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What I learned in this course:</th>
<th>did not alter my thinking about CEE</th>
<th>convinced me to stay in CEE</th>
<th>convinced me to change majors</th>
<th>left me unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2001</td>
<td>6%</td>
<td>59%</td>
<td>6%</td>
<td>28%</td>
</tr>
<tr>
<td>Fall 2000</td>
<td>27%</td>
<td>47%</td>
<td>20%</td>
<td>6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>At this point, I plan to:</th>
<th>stay in CEE</th>
<th>change majors</th>
<th>not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2001</td>
<td>72%</td>
<td>16%</td>
<td>12%</td>
</tr>
<tr>
<td>Fall 2000</td>
<td>67%</td>
<td>27%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Number of responses for Fall 2001 = 32
Number of responses for Fall 2000 = 51

Table 2. Student Responses to Survey
Concluding Comments

Based on the results of a student assessment of the course over a two-year period, it was not possible to identify a significant statistical difference between Fall 2000 (without trebuchet) and Fall 2001 (with trebuchet) responses on the impact of CIVL 102 on student interest and teaching students about Civil Engineering. Nevertheless, particularly when considering the high percentage of students who said that the trebuchet project was the most enjoyable element of the course and the high percentage who said that the trebuchet raised their interest in Civil Engineering, it was clear that the trebuchet project had a strong impact on the students.

Although the interaction between the junior and freshmen classes that was initially hoped for was not achieved in this first attempt, the enthusiasm and interest among the juniors developed for topics in the CIVL 330 course was significant. As both the freshmen and juniors move on in their academic careers, informal exchanges between them should encourage the freshmen to “hang on” for more exciting things to come.

In summary, it is clear that the trebuchet project was very well received by the students, that the project had a very positive influence on their interest in civil engineering, that team-based activities were valuable in helping them to learn about civil engineering, and that almost all students felt that projects such as the trebuchet project were enhanced by competitive aspects. Therefore, the authors believe that it is well worth the time and effort to include in first-year engineering courses a unique, competitive, team-based project that captures the imagination of the students.

References


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*ASEE Southeast Section Conference*
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