Introduction to Engineering: A Freshman Year Multidisciplinary Engineering Course and Competition

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Abstract Introduction to Engineering is a fall semester course taken by all freshman engineering students at Villanova University. The course is under the jurisdiction of the College of Engineering, which has departments in Chemical Engineering (ChE), Civil and Environmental Engineering (CEE), Electrical and Computer Science Engineering (ECE) and Mechanical Engineering (ME). During the semester faculty from each department deliver two 50 minute lectures and one three hour laboratory. This format is designed to provide a general understanding of each engineering discipline, so that freshman can make an informed decision when selecting their engineering major in the spring. Time spent with each of the four engineering departments is then unified through an end of the-semester engineering competition. The competition is designed to foster teamwork in a multi-disciplinary open-ended problem solving environment, where students work in groups designing an electrochemically powered vehicle to traverse a race course that contains flat and inclined sections, as well as designing and constructing a bridge spanning a fictitious river. The engineering departments are represented in the competition as follows: ChE) provides power to the vehicle through an electrochemical reaction, ME) design tire size and gear ratios to maximize average vehicle speed over the race course, ECE) provide wiring and electronics between electrochemical reaction and vehicle motor, and CEE) design a three-dimensional popsicle stick bridge to span the fictitious river and for test-to-failure strength at the end of the competition. Teams are ranked using an aggregate score that considers aesthetics, vehicle speed and power, and bridge strength. The objective of this paper is to explain the lecture and lab content delivered during the time spent with each department, and provide a detailed description of the end of the semester engineering competition.

Introduction

Villanova University is a Roman Catholic institution of higher education located approximately 15 miles east of Philadelphia. The college was founded in 1841 by two Augustinian friars from Saint Augustine's Church in Philadelphia. Today the university has five degree granting divisions which include the Villanova School of Business, College of Engineering, School of Law, College of Liberal Arts and Sciences, and College of Nursing. The College of Engineering (CoE) was established in 1905 and is the second oldest degree granting division within the university. The first programs within the CoE were Civil Engineering and Electrical

Engineering. Today there are four degree programs in Chemical Engineering (Che), Civil and Environmental Engineering (CEE), Electrical and Computer Science Engineering (ECE) and Mechanical Engineering. All programs offer BS and MS degrees through the respective departments. A five year program that combines the BS and MS degrees is also available in all departments, and an interdisciplinary PhD degree is administered and offered through the CoE.

The CoE offers a common freshman year to all incoming students (Table 1). As can be seen in Table 1, the first year curriculum includes two semesters of calculus, two semesters of chemistry, two semesters of humanities, one semester of theology, one semester of physics, and a two semester engineering course sequence (EGR 1700 and EGR 1705). The first of this two course sequence (EGR 1700) introduces students to the various fields of engineering, develops functional analytical and design skills, and provides formal instruction in computer aided drafting and modeling. The second semester (EGR 1705) serves as an introduction to engineering problem solving using commercially available software such as Excel, MatLab and MathCad. Both courses (EGR 1700 and EGR 1705) utilize lecture and laboratory experiences.

Table 1: Freshman Engineering Curriculum

Fall Semester	Credits	Spring Semester	Credits
ACS 1000 - Traditions in Conversation	3	ACS 1001 - Modernity & Its Discontents	3
CHM 1151 - General Chemistry I	4	CHM 1152 - General Chemistry II	4
CHM 1103 - General Chemistry Lab I	1	EGR 1705 - Engineering Computation	3
EGR 1700 - Introduction to Engineering	3	MAT 1505 - Calculus II	4
MAT 1500 - Calculus I	4	PHY 2400 - Physics I Mechanics	3
THL 1050 - Christian Theology: An Intro	3		

The current format of EGR 1700, where students are introduced to the four engineering disciplines together with formal instruction in computer drafting and modeling, is the consequence of a restructuring of the course that was undertaken in the spring and summer of 2004, and was first put in effect during the fall semester of that year. The previous course format contained only formal instruction in drafting and modeling, and lacked the engineering discipline introductions and an associated end of the semester engineering competition. The engineering faculty at VU recognized that graduating engineers of the 21st century will be expected to function effectively on multidisciplinary teams where effective skills related to team work, collaboration and communication will be necessary and valued. In response to this need, the restructured format EGR 1700 is intended to expose students (in the freshman year) to an engineering design environment that emphasizes team work, communication and the interdisciplinary nature of solving large complex engineering problems. The central element in achieving this objective is the inclusion of a semester long multidisciplinary design project that culminates in the end of the semester engineering competition (Weinstein et al. 2006). The project and competition are integrated into the engineering discipline introductions so that students understand how the different engineering disciplines work together to achieve a unified solution to a central problem.

The objective of this paper is to describe the content of EGR 1700 and show how the restructured course format achieves the objective of introducing freshman engineering students from all departments within the college to the interdisciplinary nature of the engineering profession.

EGR 1700 Course Overview

As described earlier, there are two distinct components to this course; 1) the formal instruction in computer drafting and modeling part, and 2) the interdepartmental part that provides a general overview of to the various fields of engineering and then connects the different fields through a multidisciplinary semester project and competition. The latter part of the course where students are introduced to the four engineering disciplines is co-taught by faculty from each of the four engineering departments within the CoE. The course format is structured such that each department faculty spends two consecutive weeks with the students (Table 2). The department sequence has always been Che, ECE, ME, and CEE. This sequence, however, is not the result of any preferred order, but rather determined by individual department schedule constraints. In general, a single faculty member from each department is designated to be with the students for the two week duration.

Table 2: EGR 1700 Department Schedule (each for Che, ECE, ME, CEE)

Week 1				
Monday	Tuesday	Wednesday	Thursday	Friday
Lecture 1 12:30-1:20 (Sections 2,3,4) 02:30-3:20 (Sections 7,8,9)	*Lecture 1* 1:00-1:50 (Sections 1,5,6)	*Lecture 2* 12:30-1:20 (Sections 2,3,4) 02:30-3:20 (Sections 7,8,9)	*Lecture 2* 1:00-1:50 (Sections 1,5,6)	nothing
Week 2				
Monday	Tuesday	Wednesday	Thursday	Friday
Laboratory 08:30-11:20 (Section 1) 02:30-05:20 (Section 2)	*Laboratory* 08:30-11:20 (Section 3) 02:30-05:20 (Section 4)	*Laboratory* 08:30-11:20 (Section 5) 02:30-05:20 (Section 6)	*Laboratory* 08:30-11:20 (Section 7) 02:30-05:20 (Section 8)	*Laboratory* 08:30-11:20 (Section 9)

As shown in Table 2, the two weeks of instruction (with each department) includes two 50 minute lecture sessions (taken during the first week) and one three hour laboratory meeting (taken during the second week). The intent of each department's two weeks with the students is to provide a general understanding of the respective engineering disciplines, so that they can make an informed decision when selecting their engineering major, which happens in the middle of the spring semester freshman year. Additionally, the lecture and laboratory content contribute to the knowledge and solution approach necessary for the semester project and competition.

The general format of the two lectures and laboratory components are summarized as follows:

- *Lecture 1* Provide a broad overview of the engineering discipline at hand. Describe individual specialties within that discipline, and provide specific application examples that illustrate the skills and activities that professionals, educators and researchers active in the respective specialty areas require. For example, structural engineering is a specialty area within CEE, and structural engineers use math and physics to design and analyze buildings, bridges, and other structural systems fabricated from steel, concrete, timber, and composite materials. This lecture is designed to aid the students in selecting their engineering major.

- *Lecture 2* The instructor selects one of the specialty areas introduced in Lecture 1 and provides more detailed information related to that engineering specialty. The specialty area selected is usually related to the end of the semester competition. Che presented concepts related to electrochemical reactions, and extended this discussion to the use of copper, magnesium, and citric acid. These are the same materials that will be used in the competition to construct an electrochemical fuel cell to provide electrical energy to power a motor. Theory related to rates of reaction and associated influencing factors, and voltage, amperage, and power characteristics of the electrochemical cell are presented. CEE focused on structural engineering as related to design of highway and railroad bridges. Basic bridge engineering terminology is introduced, design loads are described, and the idea of load path is discussed and related to design of the different parts of the bridge. This discussion transitions into behavior of truss bridges where concepts related to free body diagrams, external and internal loads, stresses, equilibrium and basic force-deformation relationships are presented. These topics are ultimately connected to design of a three dimensional popsicle stick truss bridge that the students will construct for the competition. ECE lectured on the integrity of electrical connections, sources of resistance in electrical circuits, and design of parallel and series circuits. Finally, ME lectured on the relationships between power, torque, gearing, and how these factors ultimately influence the mechanical performance of an electrically powered vehicle that will be built for the competition.

- *Laboratory Session* During the three hour laboratory session, students are provided with specific analytical and design information that will be necessary in competing effectively in the end of the semester competition. There are typically demonstrations and interactive exercises that compliment additional lecture material. The students are required to work in multidisciplinary groups of six or seven individuals. The net result of which is a better understanding of the engineering design environment where solutions are many and varied, but not necessarily all equally the same in terms of economy and efficiency. At the end of the laboratory session, students are fully prepared to complete their semester long project design and, hopefully, be competitive in the end of the-semester competition.

At the conclusion of each department's two week period, the students have a well rounded understanding of that particular engineering profession and are able to relate the theoretical engineering concepts presented to them to the practical needs of the end of the semester competition. To aid in making this connection more complete, faculty are available at any time during the semester to provide additional clarification as needed.

Semester Project and Competition

As mentioned above, the time spent with each of the four engineering departments is unified through an end of the semester engineering competition. The competition is designed to foster teamwork in a multi-disciplinary open ended problem solving environment. The teamwork dimension of the competition is accomplished by assigning each student to a 7 or 8 person team. Each team must then work as a group in building an electrochemically powered vehicle to traverse a race course that contains flat and inclined sections, as well as a three dimensional truss bridge spanning a 26 inch fictitious river. The race course and associated features are shown in Fig. 1. All necessary materials to build and power the car, as well as construct the popsicle stick truss bridge are provided at the beginning of the semester in a single competition kit. The students are not allowed to use any materials not included in the kit. Total cost of each individual competition kit is about $250, $230 dollars of which are for car related materials (including motor and electrochemical fuel cell supplies), and $20 for the bridge. Importantly, these kits are reused each year, so that recurring costs are limited to about $60 per kit per year.

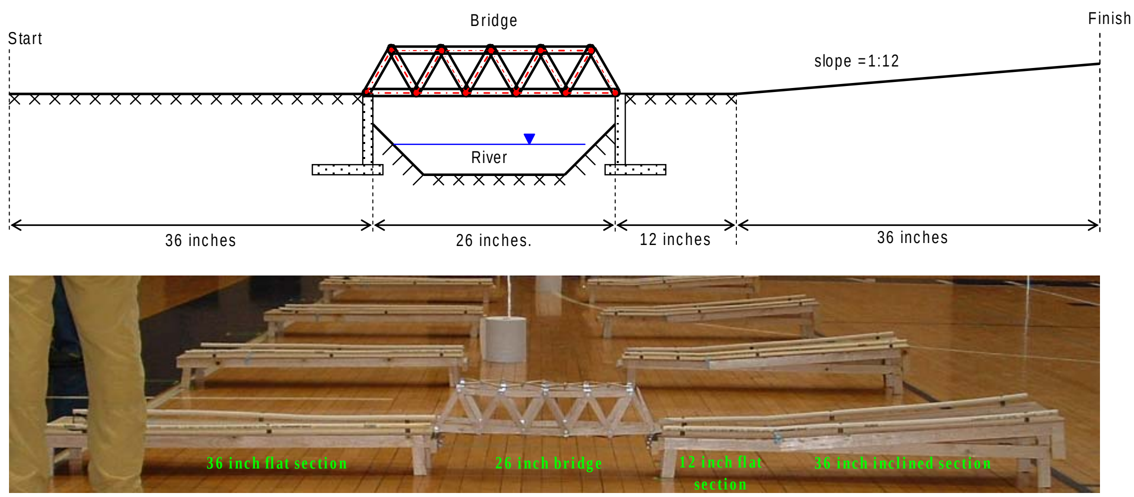


Figure 1: Engineering Course Details and Photos

The four engineering departments are represented in the competition as follows: ChE) provides power to the vehicle through a lemon juice and Magnesium oxide electrochemical reaction, ME) design tire size and gear ratios to maximize average vehicle speed over flat and inclined sections of the race course, ECE) provide wiring and electronics between electrochemical reaction and vehicle motor, and CEE) design the three dimensional popsicle stick Warren truss bridge to span the fictitious river (Fig. 1) and for test-to-failure strength at the end of the competition. At the conclusion of the competition all teams are ranked based on an aggregate score that considers vehicle and bridge aesthetics, vehicle speed and power, and bridge strength during test-to-failure.

Operational Details and Results of the Competition

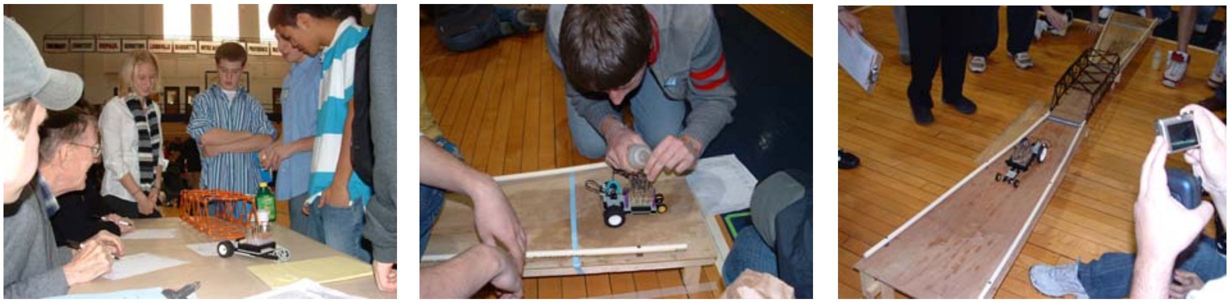
The competition is usually held in a large gymnasium between 2:30 pm and 5:00 pm on the first Friday in December. In total there are between 35 and 40 individual teams that participate in the competition. As mentioned above, there are several individual competitions that collectively represent the experience. These individual competitions include; 1) bridge and vehicle aesthetics, 2) a timed race, 3) a load pull, and 4) a test to failure of the bridge. Photos from these individual competition events are shown in Fig. 2 and results for the performance based competition events (race, load pull and bridge test) are presented in Fig. 3. In order to facilitate throughput of so many teams in the limited time period of 2½ hours, there are multiple stations for each competition so that between four and six teams are competing simultaneously at any given point in time. The individual competitions are described below.

- *Aesthetic Competition* Students are allowed to decorate their car and bridge to show their team spirit. During this competition event students must describe their car and bridge design to a panel of three judges, and answer any questions posed by the judges (Fig. 2a). Although this aspect of the competition is not directly related to performance, it does provide an opportunity to question their knowledge of engineering concepts related to their design, as well as add an artistic dimension to the experience.

- *Timed Race Competition* This is the first of the three performances based competition events. During this event, the car is first set on the start line. Then the electrochemical reaction is activated by mixing the lemon juice and magnesium (Fig. 2b). With the power flowing to the motor the car is released and timed as it negotiates the race course (Fig. 2c). As is shown in Fig. 1, the race course consists of an initial 36 inch flat section, followed by a 26 inch bridge, a 12 inch flat section, and ends after a 36 inch inclined section. The incline slope is 1 vertical to 12 horizontal. The time required to complete the course is measured by judges using stop watches.

- *Load Pull Competition* For this event the cars are connected to a digital force meter and the amount of pulling force developed by the car is measured (Fig. 2d). After leaving the timed race and before entering the load pull the teams were allowed to 'refuel' their vehicles. Each team was allowed a total of two attempts at this competition within a fifteen minute time period, with the highest value recorder as the score.

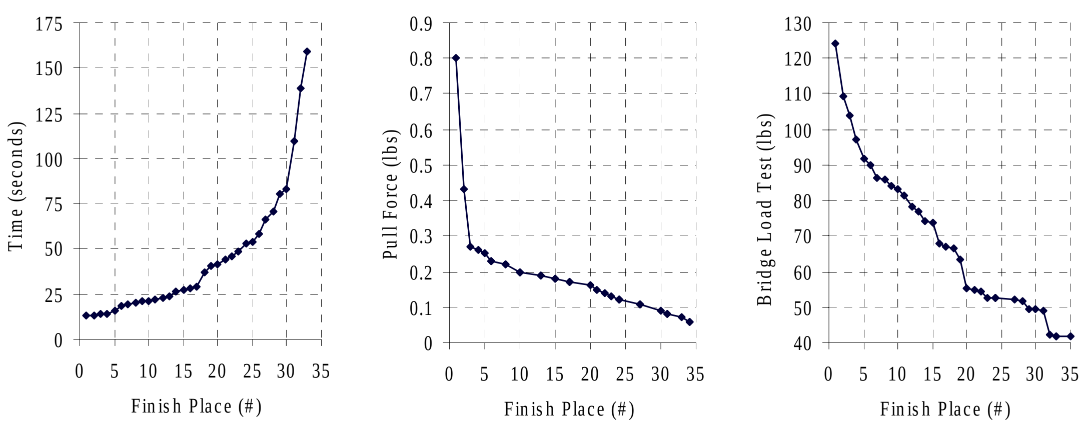
- *Bridge Load Test* The final event of the competition consisted of load testing the popsicle stick bridge to failure. This is accomplished by first setting the bridge on elevated abutments, which were formed using cylinder blocks stacked two high in the long direction. Next a deck plate was placed between the truss planes on the bottom chord and a bucket suspended from two inverted hooks fastened to the deck plate. This detail is shown in Fig. 2e. The bucket is then slowly filled with a combination of steel and sand ballast until failure is achieved (Fig. 2f). After failure, the buck is weighed on a digital scale and the failure load recorded.



a) Aesthetic Competition b) Activating the Electrochemical Reaction c) Timed Race Competition

d) Load Pull Competition e) Bridge Load Test Apparatus f) Bridge Test Near Failure

Figure 2 - Photos from the Individual Competition Events



a) Race Competition b) Pull Force Competition c) Bridge Test Competition

Figure 3 – Individual Competition Event Results

Results from each competition are used to determine individual event winners as well as the overall winner. Individual event finishes are simply based on the particular event performance.

For the overall ranking the numerical scoring system used is based on the summation of the individual event place finishes. Thus, first place is equal to one point, second place two points, etc. all the way to last place. Using this system the lowest aggregate score is the winner. Results for each the race competition, pull test competition, and bridge test competition are shown in Fig. 3, where it is noted that there was a tremendous distribution in each of the three performance based events. For the race competition, there were a number of close finishes in the top five positions (Fig. 3a). However, for both the pull force and bridge test competitions this was not the case. Referring to Fig. 3b, the first place pull test result (0.80 lbs) is almost twice the second place finish (0.43 lbs) and three times the third place finish (0.27). For the bridge test competition, the results distribution between first and fifth places was between 124.2 lbs and 91.6 lbs.

Observations and Concluding Remarks

The interdepartmental component of the ERG 1700 freshman year course has been tremendously successful. The two lectures (delivered by each department), laboratory session (delivered by each department), and end of the semester competition have achieved the objective of providing freshman engineering students with a better understanding of the individual engineering disciplines and also demonstrating the interdisciplinary nature of the engineering profession. The structure and content of the individual lecture and laboratory meetings is effective in delivering the necessary instruction to achieve these objectives. Outcomes assessment in terms of student feedback was solicited by interviewing about 10% of the entire freshman class. These students were asked specific questions designed to assess their understanding of teamwork, the individual and interdisciplinary nature of the four engineering disciplines within the CoE, and the open-ended environment of engineering design. Answers provided at the beginning and end of the semester show a definite and measurable increase in student awareness and understanding of the engineering profession as it relates to the identity of the individual engineering departments, team work, and the interdisciplinary environment of engineering problem solving.

References

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