AC 2009-1646: CENTRAL CALIFORNIA ENGINEERING DESIGN CHALLENGE: A UNIQUE COLLABORATIVE FIRST–YEAR EXPERIENCE

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Central California Engineering Design Challenge: A unique collaborative first –year experience

This paper describes a unique collaboration between the Mechanical Engineering Department at Fresno State and the engineering programs at several local community colleges to provide a mechanical design competition for first-year students at the respective institutions. The competition provides a challenging and stimulating first-year design experience for the students, and helps strengthen the relationship between the university and several community colleges that typically provide transfer students.

The Central California Engineering Design Challenge, currently in its 10th year, is a mechanical engineering design competition with the purpose of engaging students and instructors of first year engineering design courses at Fresno State and several community colleges in the Central California area. In addition to Fresno State, there are typically up to five community colleges involved in the competition, and students compete for the BEST (Brightest Engineering Student Team) award. The competition is integrated as a major component of the curriculum in the first-year design course at each of the participating institutions. The objectives of the competition are both curricular and institutional. The curricular objectives are (1) to introduce students to a structured mechanical design methodology, (2) enhance communication, teaming, and interpersonal skills, (3) have the students physically realize and test a mechanical system, and (4) to improve written and oral communication skills by documenting the entire experience through a design report and presentation. Institutional objectives are (1) to enhance recruiting efforts by creating a pipeline of students from participating community colleges, (2) enhance retention by providing an engaging "hands-on" design experience in the first mechanical engineering course, and (3) promote stronger ties between faculty at Fresno State and the surrounding community colleges. As Fresno State is an urban-campus with a large population of community-college transfers, this last point provides many dividends in recruiting, curriculum articulation, teaming on grants, etc.

The curricular benefits to the students are assessed using various instruments, including interviews, surveys and course evaluation forms. The effect on recruiting is evaluated by studying how the percentage of students that choose to transfer to Fresno State from engineering programs at participating community colleges has changed since the inception of the competition as compared to trends from non-participating schools. Retention and graduation rates of students that participated in the competition, as either a student at Fresno State or a participating community college, are compared to students that did not participate (i.e. transfer students from non-participating schools).

Introduction

The Central California Engineering Design Challenge was originally conceived in response to a growing recognition of the importance of a shared freshman design experience. It is an engineering design competition developed collaboratively by the faculty in the Mechanical Engineering Department at California State University, Fresno, (hereafter referred to as Fresno State) and engineering faculty at several local community

colleges (Fresno City College, Reedley College, Clovis North Community College, College of the Sequoias, Antelope Valley College, and Bakersfield College). It was developed as an integral part of the Introduction to Mechanical Engineering or Introduction to Engineering courses offered at each of the participating schools, which are offered in the fall semesters and are usually taken by first-semester freshmen and/or transfer students who have not previously taken an equivalent course.

Description of the competition and implementation

The engineering design challenge is implemented as a competition wherein teams of students are given a design challenge, the basic constraints and guidelines, and a period of time (several weeks) in which to design, build, and test their devices. The final demonstration and judging is performed the day of the competition, in which each team applies their device to solve or perform the specific challenge, and receives a score based on a set of point-based metrics.

The nature of the design challenge is decided prior to the beginning of the semester in a collaborative setting by the participating instructors and industry sponsors. The current industry sponsor is Sempra Energy, and in past competitions has included Chevron and Sunrise Medical Corporation. The instructors meet and discuss the competition in a round-table format, propose any new ideas, and vote on the final design challenge. Due to the fact that not all the classes involved in the competition are dedicated design courses and the curriculum may vary from school to school, the competitions have tended to adopt the following guidelines:

- mechatronics and robotics-based competitions, while very effective when integrated with an appropriate course, have suffered issues of insufficient technical preparation for this competition;
- the competitions tend to focus on mechanics and materials aspects, such as limiting the power sources to purely mechanical with no electrical or chemical power available;
- to keep the playing field level for economically-disadvantaged students, the total budget of the device is usually required to be under $25, plus any parts or materials groups can "scrounge".

Some examples of various design challenges used in recent competitions:

- Spring-powered car – students must construct a car powered only by a standard mousetrap spring. Once the car is triggered by the students, it must traverse a runway and climb a ramp and stop in a target area atop the ramp. Points are awarded for accuracy of final position inside the target area. Variations have included modifying scoring to reward vehicles carrying heavier payloads.
- Penny-delivery – students must construct a device that delivers pennies from a starting point to a target area approximately 8 ft away. The target area is constructed in a similar fashion to a skee-ball target, with raised concentric rings enclosing increasingly smaller and higher-value areas. Once triggered at the start line, the device can deliver pennies by various means to the target area (launching

through the air, rolling along a runway until striking the outer ring and then delivering via telescoping arm, etc.).

- Hacky-sack launcher – students must design a device to launch hacky-sacks into increasingly smaller diameter targets laid in a grid at increasingly longer distances (targets at 5, 10, 15, and 20 ft. from the device). Students have 5 minutes to launch 10 hacky-sacks, allowing them time to adjust the device for different distances. Each target has a point-value based on diameter and distance, with more points awarded for hitting different targets than for multiple hits on the same target.
- Penny-drop – students build device that slides down a steel cable at a 45 degree incline, automatically releasing pennies when over a target area. Points are awarded based on accuracy of final position in target area.

Figure 1: Student groups adjusting their devices for the “hacky-sack launcher” design challenge

Once the nature of the design challenge has been established, a committee member volunteers or is assigned the task of preparing a formal set of rules for the competition. These rules must be agreed upon unanimously by all of the participating instructors, and usually undergoes several iterations before the final version is solidified. Ideally, this process will be complete by the beginning of the course, but is more typically complete 2-3 weeks into the semester. At this point the students are brought into the process, as the competition and rules are announced and discussed in class, and students form their teams. Depending on the school and instructor, students may form their own teams or be assigned to teams. The size of the teams is usually restricted to a maximum of four and a minimum of two.

The next phase of the design competition is to integrate it within the curriculum of the introductory course. Students are first engaged in a series of lectures and activities on design methodology, including concept generation techniques and evaluating concepts using a decision matrix, with the design competition serving as the problem under consideration. The end result of these exercises is the selection of an initial concept that each group can then carry forward into a detailed design phase. Due to the introductory level of the course, less emphasis is placed on analytic modeling in the detailed design phase and more emphasis is placed on using solid-modeling tools to study the behavior of the proposed design concept to iteratively refine the design towards a final device. Students are required to use the CAD software tools (typically AutoCAD and SolidWorks) to produce a set of dimensioned engineering drawings of their detailed design. At this point students move into the fabrication and testing phase of the project. While students are allowed some access to shop facilities and tools on-campus, most of the fabrication is done off-campus by individual groups. At this point in the process each group is required to meet with the instructor to have their initial prototypes evaluated and obtain feedback and advice from the faculty. Students then go back and complete their design and prepare for testing. One day is set aside for testing, typically about a week prior to the competition. The instructor provides a physical mock-up of the design competition apparatus (ramp, platform, target, etc.) and each group is allowed a certain number of test runs to evaluate the performance of their designs and determine any final modifications that may be required before the competition. Each group is graded on their devices performance in the test procedure, both to assess the viability of success of their design concept and as a means to keep student groups on track to complete their devices and perform well in the competition.

The final phase is the competition itself. It is traditionally held on the first Saturday in November, approximately nine weeks into the semester. The competition was originally held in a large classroom, but participation and attendance has grown from approximately 50 people at the inception to upwards of 250 people in recent years such that it is now typically held in a large gymnasium or pavilion. Attendees typically include family and friends of participants, interested students and faculty, and some local media coverage. Student teams must register and have their devices inspected by the team of judges to ensure conformity to the rules. The devices are then impounded until the groups turn to compete in the event. Once all devices are impounded, groups are called at random to

have their device perform the required challenge or task. Typically, this phase of the competition will consist of an elimination round, where the top 5-10 (depending on the nature of the competition) groups will move on to a final round. Devices must be returned to impound after each groups run to eligible for the final round. Once the initial round is complete, the scores are tallied and a determination is made as to which groups may proceed to the final round. The selected groups again have their devices perform the prescribed tasks in the final round, and the scores are tallied to determine a winner. In the event of a tie, subsequent rounds may be necessary. Often, the challenge may be increased in difficulty between elimination and final rounds, and particularly in any tie-breaker rounds, such as decreasing target size, decreasing the amount of available potential energy, etc., depending on the nature of the challenge. Once the winner is determined, the participants break for a buffet lunch and then an awards ceremony is held, with first, second, and third place prizes awarded, as well as Best Overall Design and Most Original Design. The winning team's school takes possession of the Design Challenge trophy and gets to keep it until the next year's competition.

Figure 2: Panorama view of 2007 design challenge competition

Curricular Benefits

The competition was first conceived as a response to an ABET review recommendation to incorporate a freshman design experience into the curriculum. At this point the idea of developing a joint experience with some of the partnering community colleges that provide the majority of the transfer students was conceived. The competition is integrated as a major component of the curriculum in the first-year design course at each of the participating institutions. The curricular objectives are (1) to introduce students to a structured mechanical design methodology, (2) enhance communication, teaming, and interpersonal skills, (3) have the students physically realize and test a mechanical system, and (4) to improve written and oral communication skills by documenting the entire experience through a design report and presentation.

To assess the possible benefits to the curriculum and general student response, a survey was prepared and given to 64 students in the introductory course who participated in the 2008 competition, as well as a cross-section of third- and fourth-year students who participated in past competitions (45 students). Seven questions were common to the two surveys, with the final question differing between the two groups. Students were asked to either agree or disagree with each statement, with the scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The results of the survey are displayed in Table 1.

Table 1: Student responses to survey questionnaire

	Survey of Past Participants	Standard Deviation	Survey of Fall 2008 Participants	Standard Deviation
The type of project was appropriate for the class	4.4	0.9	4.4	0.9
Level of difficulty was appropriate for the class	4.1	0.9	3.8	1.1
Amount of given time was adequate	3.9	1.2	3.5	1.1
Project encouraged to continue as ME major	3.6	1.1	3.9	1.0
Percentage of the grade corresponds to work put into it	3.6	1.2	3.5	1.1
Project improved my knowledge of mechanical engineering	3.3	1.1	4.3	0.8
Project improved my ability to work in groups and team management skills	3.9	1.1	4.4	0.7
Good method to introduce freshman to mechanical design	4.2	1.0	Not asked	
Had fun doing the project and participating in the competition	Not asked		4.2	0.9

Looking at the survey, we can see that the student feedback is generally positive. Both groups of students report a high level of agreement that the type of project is appropriate for the course. There is less agreement that the level of difficulty and time allotted were appropriate, indicating that instructors may want to investigate reducing the difficulty level of the competition or providing more resources, such as class-time spent conveying necessary knowledge and available lab time to fabricate and test projects. Both groups seem to indicate a lower level of agreement that the percentage of work required matched the amount of work required, which tracks with the previous statement. Students that had just completed the competition were more apt to agree with the statement that the competition improved their knowledge of mechanical engineering than the upper-division students surveyed; this may be a result of upper-division students having a broader perspective on what mechanical engineering entails. Students just completing the competition were also more likely to respond positively to the statement that the competition encouraged them to remain in the mechanical engineering major than upper-classmen surveyed; while this is positive from the point-of-view of one-year retention

and matches observed increases in retention rates, the lower score from upper-classmen warrants further investigation as to how the retention aspects of the competition can be improved. Both groups reported good agreement that the project improved their teamwork and group management skills, which is encouraging as it was a specific curricular outcome of the course. Finally, upper-classmen surveyed indicated that the competition was an effective means to introduce first-year students to the mechanical design process, which is the primary curricular objective.

Participating students and faculty were also asked to reflect on their experiences with the competition. Some comments from the students include:

"The ME-1 competition boosted my interest in an engineering discipline because the various awards that were given or noted. It's important to have applications as well as general computation skills."

"The ME-1 competition is a great event to give engineering students a first-hand experience of what it's like to design, build and test a project."

(Note: The competition is informally known among the students as the ME-1 competition after the introductory course number.) The following quotes from two of the community college instructors provide some faculty perspectives:

"The competition is a great way to tie in the concepts of the engineering design process, team work, and project scheduling. The hands-on aspects of the competition are great because it gives the students a chance to make a physical product while they are in the midst of taking calculus, chemistry, physics, etc. It keeps in focus the concept that engineers turn ideas into reality."

“The design competition is always a highlight of our Introduction to Engineering course. It demands the most out of the students, and many students really excel with the challenge. After attending the competition, students are very motivated by seeing so many students that are also pursuing a degree in engineering. The pride that students feel in competing well in such a large event also helps develop their confidence at school.”

While the information garnered from the informal interviews is anecdotal, we can see that both students and faculty carry a positive view of the competition and indicate that it achieves the overall goal of providing a fun and engaging “hands-on” design experience.

Benefit of Community College Collaboration

One of the primary benefits of the collaboration between the university and the participating community colleges is the formation of strong ties between the faculty, which benefits instructors at both the university and the community college. Some examples of benefits coming out of this strong relationship include:

- Direct access to engineering students without having to go through counselors and other administrators. Professors have been invited many times to come and speak

to classes at the participating community colleges about the mechanical engineering program at Fresno State, to recruit for the industrial internship program, help organize and judge design contests at the community colleges, and other activities to promote engineering studies.

- Stronger ties between the faculty has resulted in instructors from the participating community colleges teaching certain courses at the university on a part-time basis.
- More open lines of communication between the engineering programs at the community colleges and the university. One benefit of this is direct and timely feedback on how curricular and other institutional changes at the university may enhance or adversely affect programs at the community college level. For an urban campus that has a large number of community college transfers, a good understanding of interrelationships between programs at both levels is essential.

The importance of personal relationships between the faculty cannot be overstated. Instructors at the community colleges know who to call if they need information on transferring to the program, articulation, need to access university resources or team on a grant proposal or research project.

Effect on recruiting and retention

One of the objectives when the competition was originally conceived was to enhance recruiting efforts from the local community colleges by creating a joint experience that would allow students to interact with students and faculty from the university and have a chance to visit the university and facilities on the day of the competition. This aspect of the competition is typically focused on the day of the event itself, as that is when most of the interaction occurs. Student volunteers form the ASME Student Section are typically recruited to help organize and run the event, and these students make an effort to interact with the visiting students, relate their experiences about the university and the mechanical engineering program, and answer questions the visitors may have.

Participants in the design challenge that are visiting the campus from other schools often bring their friends and parents, and this provides another excellent opportunity to showcase the program and university. Parents are often more engaged in seeking out current students and faculty to ask questions and to observe student projects and facilities. Having additional faculty present who are not directly involved in running the competition, as well as showcasing current student projects in the registration area is a productive means to take advantage of this opportunity. Additionally, in recent years the department has begun to have the competition and the College of Engineering Open House coincide to provide maximum exposure to the visiting public.

To investigate the impact of the competition on recruitment from local community colleges, the numbers of transfer students from the participating community colleges were compared with the overall numbers of transfer students from all community colleges into the Mechanical Engineering program and the College of Engineering[1]. The three community colleges that have been the longest active participants were used in this study. The number of total transfer students from these three colleges into the ME program is plotted in Figure 3 from 1997 (two years prior to the inception of the competition) through 2008, along with the total number of transfer students into the ME

program for the same time period. While the figure shows a general upward trend in the number of transfer students from both participating community colleges and all community colleges, it is difficult to draw any statistically valid conclusions; this is partly due to the small sample size of students transferring from participating schools and partly to the fact that this is one of many activities designed to recruit students from the community colleges and we cannot necessarily isolate the impact of any one activity. At best we can conclude that there is no negative impact on recruitment.

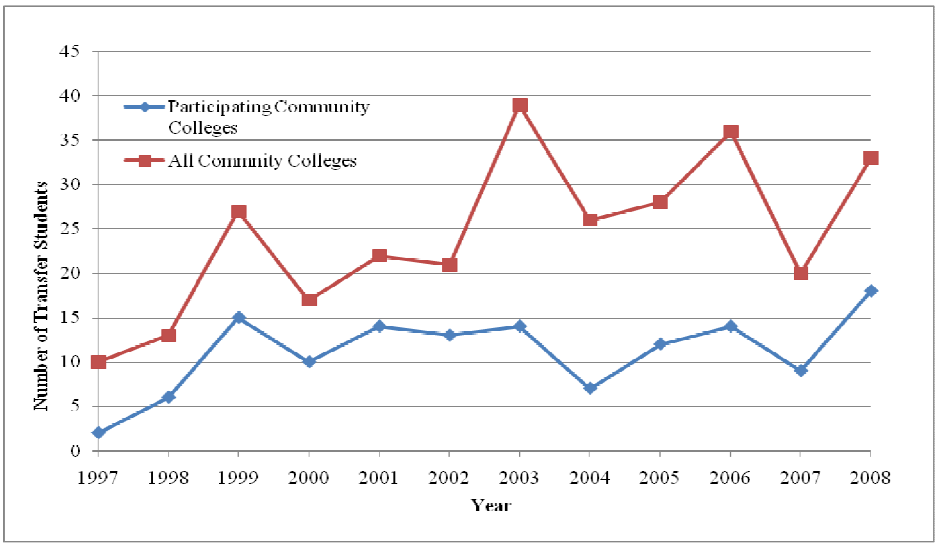

Figure 3: Number of transfer students into the Mechanical Engineering program from primary participating community colleges

Another major goal of the competition is to enhance retention of first-year mechanical engineering students by providing an engaging "hands-on" design experience in the first mechanical engineering course. The one-year retention rates for freshman mechanical engineering students from 1997 through 2007 are shown in Figure 4[1]. Since the inception of the competition in 1999, we can see a general increasing trend in retention rates. Again it is difficult to draw statistically valid inferences regarding the freshman design experience in isolation, as there was no level of control over the myriad of other factors that can affect retention rates, but coupling the slight upward trend seen above with the generally positive feedback from the student surveys, we can conclude that the competition is having an overall positive impact on student retention.

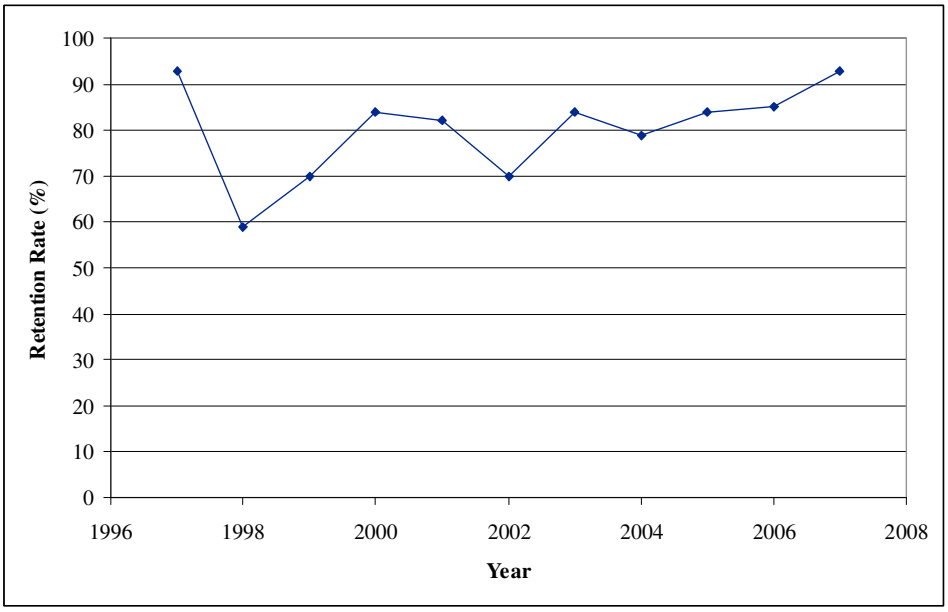

Figure 4: One-year retention rate for students beginning as freshmen in the mechanical engineering program

Conclusions

- Even though it is difficult to separate the event from other recruitment efforts, an increasing trend in the number of transfer students into the ME department combined with the positive feedback regarding the event among current students suggest that the competition is successful in attracting students into the program.
- One-year retention rates have increased from 70% to over 90% since the implementation of the competition. While it is difficult to attribute this to the competition alone, that is the single most significant change in the freshman curriculum in that time period.
- Response from the student survey and interviews indicates that students consider the competition to be an effective means to introduce freshmen to mechanical engineering design and to increase the level of student enthusiasm about studying engineering.
- Strong ties between university faculty and community colleges instructors have developed since the introduction of the competition, permitting more interaction among them and better channels of communication between the community colleges and the university.

Bibliographic Information

1. Institutional Research, Assessment, and Planning at California State University, Fresno Report, prepared for Ira Sorensen, 2009.