A Golf Ball Launcher as a Sophomore Design Project

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Abstract

The first engineering course taken by mechanical engineering students at the University of Houston requires completion of a design, fabricate and compete team project. The project that was completed during the Fall 2004 semester is described in this paper. The two "pronged" project evaluation process (testing results and direct assessment) is described and the results are given. Pictures of the better designs are provided. Personal and demographic data were gathered on the individuals in the class, but it is shown that team performance may be more a function of such mundane issues as the scheduling and logistics difficulties for team meetings than the effects of these individual measures. Results from surveys indicate less than a 2% dissatisfaction rate (one student in 56) for the project and over 80% support (non-negative and non-neutral) that the course outcomes were satisfied.

Introduction

At last year's ASEE GSW Annual Conference, Tariq Khraishi[1] presented a paper in which he described how the "golf ball launcher design project" was introduced into two sections of an existing junior level dynamics course. The objective of the project was to design, fabricate and successfully test a device that would propel a golf ball through a 20 cm diameter opening, located one meter above the floor, from at least one meter away. A variety of devices utilizing slides, springs, elastic bands and pendulums were described. A second paper[2] was presented that described in detail one of the student team solutions. The project was introduced into the course as an example of "problem based learning". At first glance the project provided the usual benefits of a team based, open ended, hands on design project in which "performance" was an easily quantifiable measure of success (i.e., design, fabrication, and testing of hardware based on a concept selected from several viable alternatives). However, the fact that the students were responsible for a credible analysis of the performance of their devices based on the material taught in the dynamics class distinguished this project from most other "lower level" design projects, since it represented "engineering design" (assuming they did the analysis first) as opposed to a "cut and try" design. The students gave 100% support to the question of whether the project enhanced their understanding of "projectile particle motion" and "the work energy equation". Seventy-four per cent agreed that the enhancement was "significant." All in all this was a very successful experiment. This current paper describes how the

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same basic project was “adopted” (stolen) and used as the major project for a sophomore design course, a course that has only drafting and writing as prerequisites.

Details concerning the content and conduct of the sophomore course in which the current project was assigned are given in three papers[2-5]. As usual in this class the design’s performance was determined in a very public testing event but counted for only 20% of the project grade. The entire project counted for 45% of the individual’s course grade. There were four reporting requirements (three written reports [two progress and one final] and a final oral report), a final validation process, a final design review, and a prototype testing. The paper will contain the detailed problem statement, the results of the testing, pictures of the more successful designs, and a summary of student reaction and feelings about the project.

Project: Golf Ball Launcher

Besides the increased emphasis on other aspects of the design process, e.g., documentation and the artifact itself, there were changes in the problem statement (from the Khraishi project) that made the project more “design oriented” and less “engineering design oriented”. The changes were:

- The openings (targets) were reduced to 5-inches in diameter.
- The distance from the target was increased to 5 feet.

The additions were:

- There were constraints imposed on weight and size of the device and on operator contact with the device.
- Multiple performance requirements were imposed (two different targets for which the device had to be pre-calibrated (no practice)).
- Constraints (requirements) were placed on performance (five successful launches per eight attempts [four at each target]).
- Goals were established (eight successful launches out of eight attempts, and a preference of a gravity-driven, light-weight design).

An eight-page document completely describing the project was given to the class on August 24th, the first class meeting. The project continued throughout the semester. An Initial Testing or test of concept occurred on October 11th: propel two of three golf balls through one, large opening. The Final Testing occurred on November 3rd. A summary of the project and the requirements for the Final Testing is given in Figure 1. Twelve teams of four students and two teams of three students each worked on the project.

Results

As noted above 20% of the project grade was based on its performance during the Final Testing. Twenty-five per cent is based on an assessment of the design concept and the artifact by the instructor. Both of these aspects of the evaluation process will be addressed in this Results section.

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The actual rules for operations and scoring for the Final Testing are somewhat more complicated than those described so far. Some of those "complications" are noted here:

- The first round of testing was without penalty; unsuccessful teams continued to test with a 25% reduction in score for each round required.
- Bonus points were awarded for lightest and for the most accurate devices.

Nine of the fourteen teams were successful (made at least 5 of 8 attempts with a device weighing less than ten pounds) in the first round. Four teams were 8 for 8; one team was 7 for 8; three teams were 6 for 8; and one team 5 for 8. Their weights varied from 1.2 pounds to 8.3 pounds. The resulting figures of merit (fom) ran from 29 to 63 (8 for 8 with the lightest device). One team was successful in the second round (fom = 20); and two, in the third round (fom = 19 and 24). Two teams were unsuccessful after three rounds and received zero for 20% of the project grade.

PROBLEM STATEMENT

Design, fabricate and test a device that will "propel" a golf ball through an opening from a distance of at least five feet. The device shall weigh less than ten pounds (the lighter the better) and shall fit within a cube, 30 inches on an edge before "deployment." For the Final Testing there shall be two openings; both shall be 5.0 ± 0.2 inches in diameter with centerline distances at 20.0 ± 0.5 inches and 40.0 ± 0.5 inches above the floor There are no restrictions on the type of energy used, but there can be no external power source. However, designs using gravitational energy will be viewed more favorably than those using other forms of energy. Batteries are allowed but chemical explosions are not.

THE DEVICE

Under no circumstances shall the device cause harm to the operators or the audience nor damage to the room or its contents. The "mechanical" subsystems of the device must be constructed by the members of the team but may contain prefabricated mechanical components such as gears, hinges, pulleys, wheels, bearings and shafts. Normal, simple fasteners such as screws, nails, bolts, rivets, tape, glue, etc. may be utilized. No "sticky materials" (e.g., tape) is allowed to hold the device in place, although suction cups are acceptable. Nothing is allowed to penetrate the floor, e.g., tacks. No damage (either physical or esthetic) shall be inflicted on the floor, the room or its contents.

OPERATIONS

The initiation of operation shall be in the form of a simple "release" and shall not transfer any energy to the device or the golf ball. After the release, no intervention with the device, the golf ball, the "opening" or its structure or the floor will be permitted.

FINAL TESTING

The requirement for a successful Final Testing is to propel five out of eight golf balls through the designated opening while attempting the process four times at each height. Teams will bring their devices to the common testing area and will be allowed three minutes to set up and practice initially, fifteen seconds to "reload" between activations at a given height, and one minute to adjust their device when the height is changed. In addition to the Final Testing requirements and constraints, the goals are:

- to successfully propel all eight golf balls through the openings and
- to minimize the mass of the device.

Specifically, the goal is to maximize the figure of merit, FM, defined as

$$FM = 4*N + 3*(10 - \mu)$$

where N is the number of times golf balls successfully pass through the opening and μ is the weight of the device in pounds ($0 \le \mu \le 10.00$).

Figure 1: Synopsis of the Golf Ball Launcher Project.

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The assessment of the design concept and the artifact was done using the criteria identified in Table 1. Based on a grade point average, i.e., 4=A; 3=B, etc. the assessments ranged from 0.86 to 4.25 (average =2.96 ± 0.96).

Concept: originality, satisfying the goal of using gravity	20%
Creativity: execution of the concept, e.g., design development, materials, etc.	20%
Robustness: confidence and repeatability	20%
Esthetics: craftsmanship	15%
Description: written operating instructions and salesmanship	15%
Attention getting: was it noticed?	10%

Table 1: Criteria for Design Assessment

Figure 2 (Dates on all photographs are incorrect.) illustrates the testing configuration and the target. During the Initial Testing the device was required to propel two of three balls through the larger, middle opening. During the Final Testing the requirement was to propel five of eight ball (four "shots" at each opening) through the openings with the goal to propel all eight through the two openings.

The interesting aspects of these projects are to see the students' choices for the design concepts, how these concepts are brought to reality, and finally how they perform. The fourteen teams selected five distinct concepts as listed in Table 2 and presented in the indicated figures:

- pendulum (Figs. 3 to 5),
- canon compression spring (Figs 6 and 7),
- external extension spring (Figs. 8 and 9),
- torsion spring (Fig. 10), and
- rubber bands.

Concept	Number of Devices	Avg. Final Testing Grade	Avg. Device Grade	Avg. Grade
Pendulum	5	3.3	3.9	3.6
Compression Spring	2	3.4	3.4	3.4
Tension Spring	4	2.1	2.5	2.3
Torsion Spring	1	4.5	3.4	3.9
Rubber Bands	2	1.9	1.2	1.5

Table 2: Breakdown of Devices and Grades

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Figure 2: Target

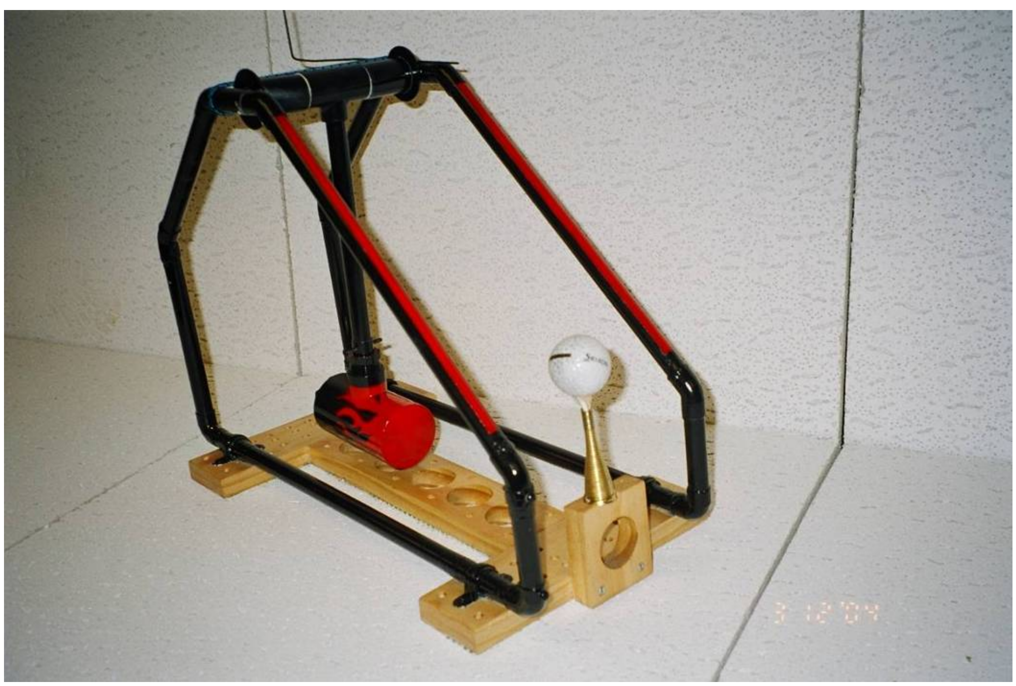

Figure 3: Pendulum Design; Tee Height Adjusted by Replacement

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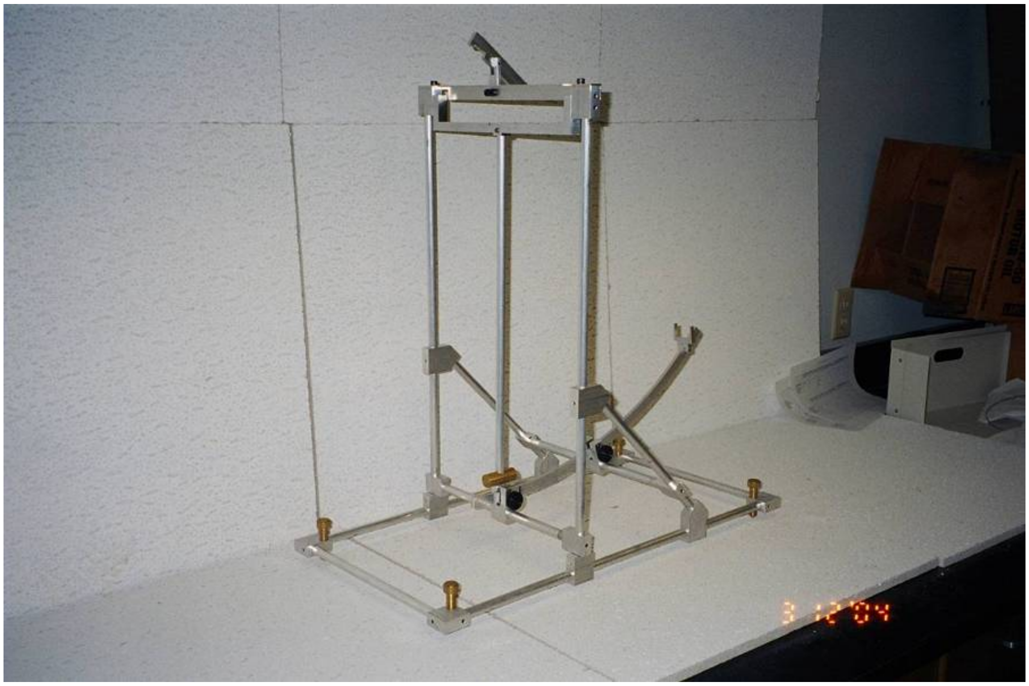

Figure 4: Pendulum Design: Continuous Tee Adjustment

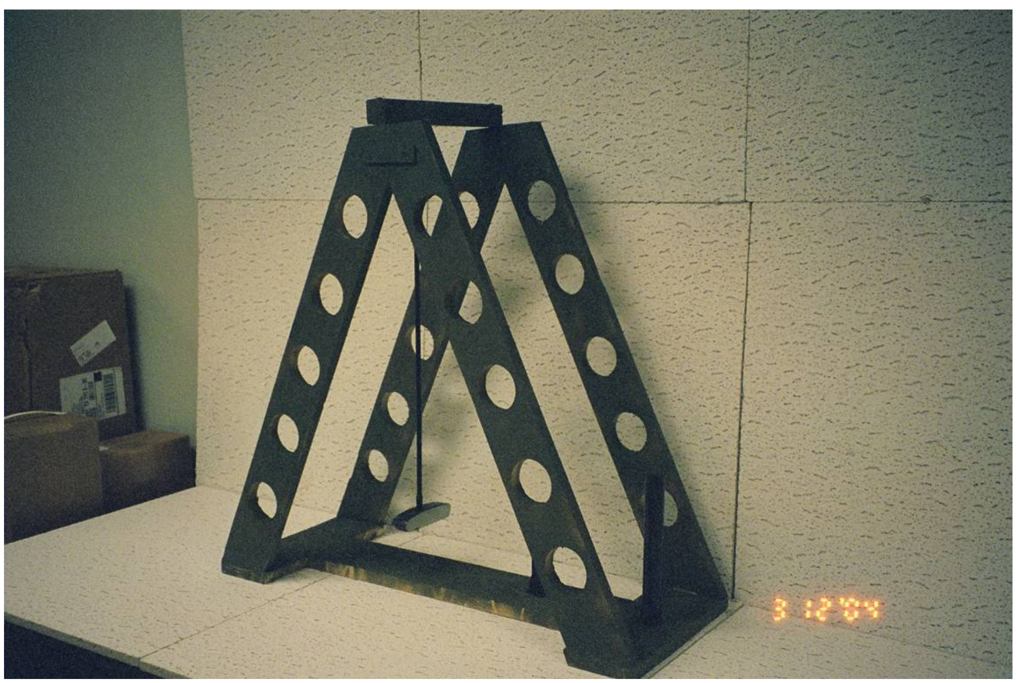

Figure 5: Pendulum Design: Tee Height Adjusted by Replacement

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Figure 6: Internal Compression Coil Spring: Adjustable Tilt

Figure 7: Internal Compression Spring; Adjustable Tilt

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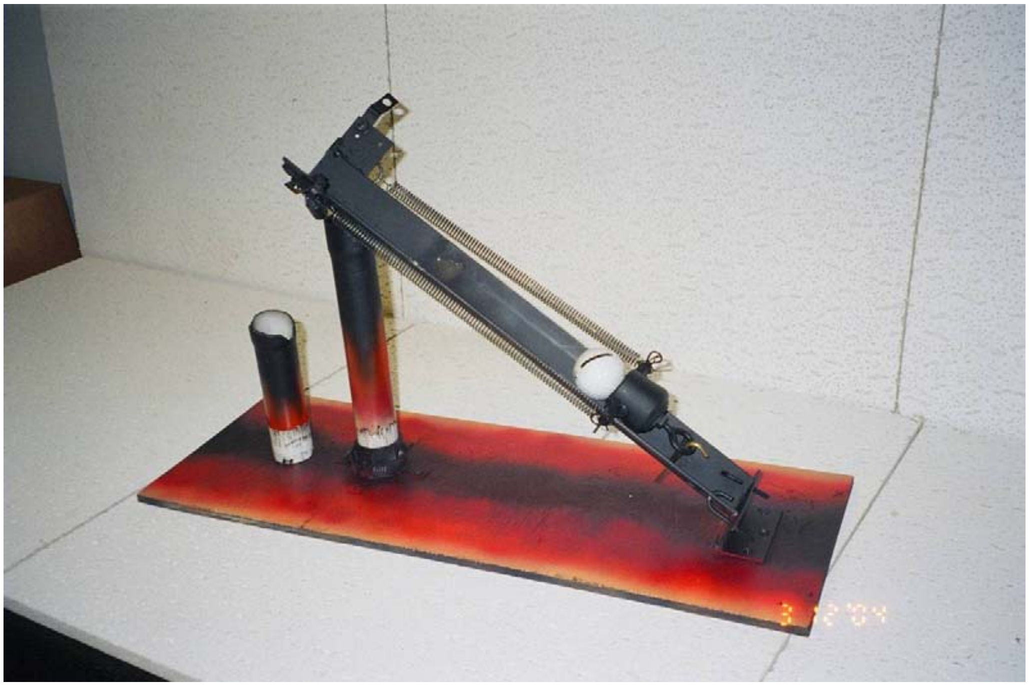

Figure 8: External Extension Spring: Adjustable Tilt

Figure 9: External Extension Spring; Adjustable Tilt

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Figure 10: Torsion Spring; Multiple Tees

Table 2 also provides information related to the evaluation of the designs. The Final Testing is based entirely on performance (the Figure of Merit, See Figure 1) while the Device Grade is a subjective evaluation based on the grading rubric given in Table 1. There was a two-week time interval between the Final Testing and the Device Grading, and teams had the option of improving and even completely rebuilding their devices. Most improved them; none rebuilt. The torsion spring device (Fig. 10) excelled in the Final Testing because it was accurate (8 for 8) the by far the lightest (1.1 pounds). However, it lost points in the design evaluation for its over-powered, non-gravity concept. The pendulum designs did well, but they were difficult to build so that many opted for the simpler but less accurate spring and rubber band designs. Both of these designs suffered from poor reliability, due to poor repeatability in execution and failure of materials (the deteriorating elastic properties of the stretching parts and wear and tear on and even failure of the support structures).

Some of the more successful teams are presented in Figs. 11 to 14. These pictures also illustrate the diverse nature and skills of our students. For example, the youngest Launch Pro (Fig. 11) is 33 years old; two have engineering degrees already; and all work full time in engineering or engineering related jobs. The All-Stars (Fig. 12) represent four cultures, speak a total of nine languages and have three undergraduate degrees and one master's degree. The Afterburners (Fig. 13) represent three cultures and include one varsity track athlete. The Drivers (Fig. 14) include the holder of a poultry science degree and two machinists who were able to machine their device completely from aluminum stock, including the leveling and set screws.

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Figure 11: Launch Pros; Torsion Spring Design

Figure 12: The All-Stars; Pendulum Design; Adjustable Tilt

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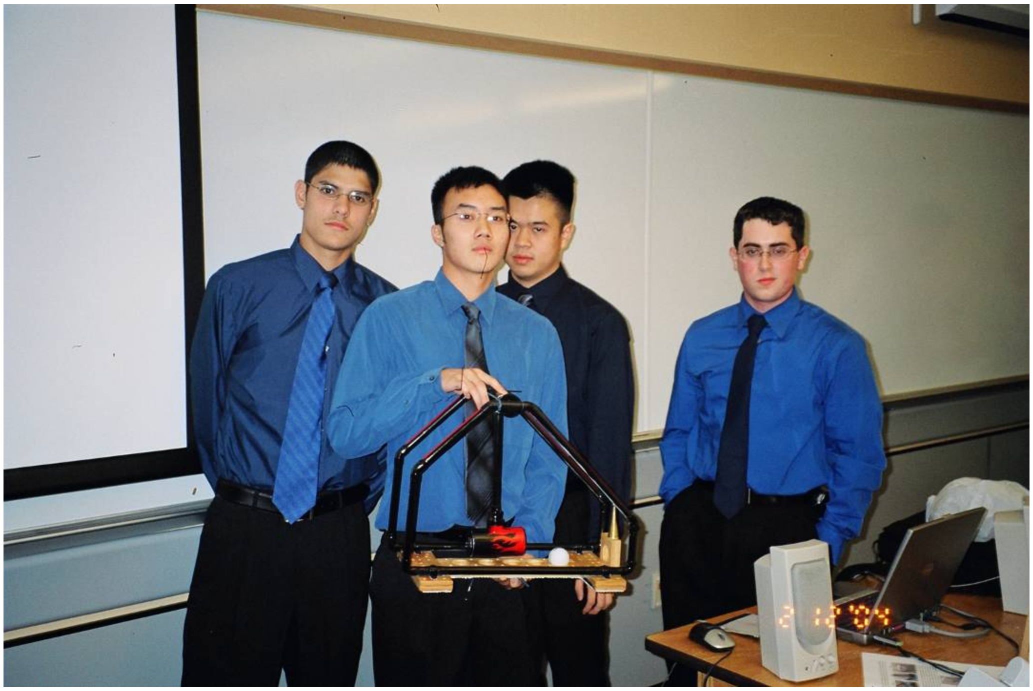

Figure 13: The Afterburners

Figure 14: The Drivers with Built from Scratch Pendulum

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The demographic/academic data for the class is usually taken at the beginning of the semester. A summary of some of the results of that survey are show below:

1. Forty per cent of the students were born in the greater Houston area, and 32% were born outside the USA.
2. Seventy-seven per cent graduated from a high school in the Greater Houston Area; 11%, from a high school outside the USA.
3. Only 12 of the 44 reporting (27%) came to the University of Houston directly from high school.
4. Seven associate, 3 BA/BS and 1 MFA degrees had already been earned by ten individuals in the class.
5. All but one student has access to a computer at home, and all but two have internet access at home. However, only 37% own their own laptops.
6. Fifty-two per cent claim "medium" or "high" competency with AutoCad, but only 7% and 6% claim "medium" or "high" competency with Matlab and ProE, respectively.
7. Not counting those with degrees (which would raise the average) the students in the class have already earned an average of 54 hours of college credit (Following the UH BSME degree plan students should take this course at the beginning of the sophomore year at which time they would have completed only 29 hours.)
8. Sixty per cent are currently working; seven per cent are looking. Expected average work load during the semester (including those not expecting to work) is 16 hours a week.
9. All students claim at least "medium competency" with Word; 63%, with Excel; and 68%, with PowerPoint.

Discussion

This class was also used to gather data that might lead to a better understanding of what individual characteristics or combinations of those characteristics might make teams more effective. The results of that study (which included data from four classes over two years) will be presented in Reference 6 and will report that there was only a weak or no correlation between team performance and the average characteristics of the team members (e.g., gender, ethnicity, age, experience, academic prowess, personality indicators, team citizenship and interest). However, it is clear that some teams do better than others. In an attempt to learn more about the origins of team effectiveness, the following statement (Figure 15) was added to the normal end-of-the-semester questionnaire in the course. The number of times a response occurred in the "top three" for any of the 54 students in the class was counted with the results tabulated in Table 3. Therefore, despite considerable support for the idea that "diversity" improves team performance, there may be times when other considerations dominate. Such practical issues as rigid personal schedules and long travel times may "sink" a team.

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Please place the appropriate numbers ("1" for most effected, "2" for second most effected, etc.) in the spaces to the left of the phrases below that best complete the sentence: **"The effectiveness of my team was reduced because of……**

_____ conflicting work/class schedules
_____ long travel distances for meetings
_____ personality conflicts among team members
_____ one (or more) disruptive team members
_____ one (or more) disinterested team members
_____ our inability to establish a team leader
_____ too many team leaders
_____ ______________________________(fill in any other reason)

Figure 15: Request on End-of-Semester Questionnaire of Design Class in Fall 2004.

# of times	%*	Completing Phrase
37	69	conflicting work/class schedules
27	50	long travel distance for meetings
12	22	one (or more) disinterested team member(s)
9	17	personality conflicts among team members
5	9	one (or more) disruptive team member(s)
5	9	our inability to establish a team leader
2	4	lack of time
1	2	too many team leaders
1	2	poor decision making
1	2	arrogance
1	2	lack of resources

* Per cent of times this response occurred in the top three for the 54 completed questionnaires

Table 3: The Number of Times that the Indicated Response Occurred in the "Top Three". The Responses Completed the Statement, "The Effectiveness of My Team Was Reduced Because of….."

As part of that same end-of-the-semester survey students were asked to indicate their level of agreement and disagreement to a series of statements about their feelings and accomplishments in the course. These results are tabulated in Table 4. The first seven statements are taken from ABET Criterion 3 and are those judged to be appropriate outcomes for a sophomore design course. The rest of the statements relate to their feelings about the course. Overall about 5% gave negative responses (strongly disagreeing or disagreeing with a "positive" statement about the course or their feelings about the course). Eight-one per cent provided a positive response (strongly agreeing or agreeing). As is usually the case, most engineering students enjoy team projects and support the premise of "friendly" competition.

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5[1]	4	3	2	1	N[2]	mean	sigma	**I feel that I improved my**
31	16	4	4	1	56	4.29	0.99	ability to design a system, etc.
30	18	3	4		55	4.35	0.88	ability to function on a team
20	23	8	5		56	4.04	0.93	ability to identify, formulate, and solve engineering problems
24	20	10	2		56	4.18	0.85	understanding of professional and ethical responsibility
20	22	12	2		56	4.07	0.84	ability to communicate effectively
27	16	10	2	1	56	4.18	0.97	understanding of the impact of eng'g, etc.
27	13	13	3		56	4.14	0.95	understand the need for life-long learning
								I enjoyed
37	13	3	2	1	56	4.48	0.89	working on the projects
34	14	6	1	1	56	4.41	0.88	working on a team
40	9	6	1		56	4.57	0.75	the friendly competition between teams
40	8	8			56	4.57	0.73	seeing how others solved the problems I struggled with
28	18	8	2		56	4.29	0.84	I am proud of my effort in this course.
29	17	5	4		55	4.29	0.91	I am proud of my team's effort in this course.
27	16	9	3	1	56	4.16	1.00	I am proud of my team's "solution".
34	15	6		1	56	4.45	0.82	I liked the fact that there were peer evaluations.
28	19	7		1	55	4.33	0.83	My team work skills have improved.
29	17	6	3	1	56	4.25	0.97	My technical writing skills have improved.
24	16	11	2	3	56	4.00	1.12	My planning and time management skills have improved.

[1] The students were asked to express their level of agreement or disagreements with each statement using: 5 for strongly agree; 4 for agree; 3 for neutral; 2 for disagree; and 1 for strongly disagree.
[2] Not all students responded to all statements.

Table 4: Results from End-of-the-Semester Questionnaire

Conclusions

A team design, fabricate, and compete sophomore design project has been described. The results have been presented and representative artifacts and teams pictured. The student response to the project, as usual, was very positive. This project is typical of those that have been given in this course each semester since 1991. No formal analyses are required, and this type of project is clearly not an "engineering design" project. However, students do learn, or at least appreciate, (in retrospect) the value that pre-design analyses would have brought to their design process. They also appreciate, many for the first time, the difference between a "paper design" and a properly functioning "artifact" of design.

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References

1. Tariq A. Khaishi and Larissa Gorbatikh, "Educational Experiments in Problem-Based Learning for a Dynamics Course," presented at the 2004 ASEE Gulf-Southwest Annual Conference, Texas Tech University, March 10-12, 2004. Available on Conference CD (paper 38)
2. David G. Johnson, Jessica D. Sanders, and Gregory S. Mowles, "A Golf Ball Launcher: An Engineering Dynamics Project", presented at the 2004 ASEE Gulf-Southwest Annual Conference, Texas Tech University, March 10-12, 2004. Available on Conference CD (paper 34)
3. Richard Bannerot, "Experiences in Teaching Sophomore Design in Mechanical Engineering," presented at the International Conference on Engineering Education 2004: Global Excellence in Engineering Education, Gainesville, FL, October 16-21, 2004. Available on Conference CD and posted at conference website: http://www.ineer.org/Welcome.htm
4. Richard Bannerot, "The DO's and DO NOT's for Major Projects in an Introductory Design Course", presented at the 2002 ASEE Annual Conference and Exposition, June 16-20, 2002, Montreal, Quebec, Canada. Posted on the ASEE website: http://www.asee.org/about/events/conferences/search.cfm .
5. Richard Bannerot, "Evaluation of Design, Build and Complete Projects," presented at the 2001 Annual Conference of the ASEE Gulf Southwest Section, March 28-30, 2001, College Station, Texas, on conference CD
6. Richard Bannerot, "Characteristics of Good Teams," accepted for presentation at the 2005 ASEE Annual Conference and Exposition of the ASEE, June 12-15, 2005, Portland, OR.

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