# AC 2008-808: ASSESSING STUDENT WORK IN AN INTRODUCTORY DESIGN CLASS

**Richard Bannerot, University of Houston**

Richard Bannerot is a professor of mechanical engineering at the University of Houston. His research interests are in the thermal sciences and engineering education, especially heat transfer, alternative energy, thermal system design, and design education. He is a registered professional engineer in the State of Texas.

# Assessing Student Work in an Introductory Design Class


## Abstract

Assessment of student work in an engineering design class can more subjective than most engineering students (and sometimes faculty) are comfortable with. Students, and faculty alike, may be more comfortable with a more quantitative grading scheme. Such an approach has been developed for use in an introductory design class in which the process of design is emphasized over the product of design. This paper presents the summarized versions of the assignments in the class offered in the fall of 2007 and completed by 68 students. Twenty-five per cent of the course grade was determined from team performances on a two-month long, design, fabricate and test project. Seventy per cent of the team project grade was based on quantifiable components such as test results and reporting requirements leaving only 30% of the project grade (or about 7% of the course grade) to be determined from a "subjective" evaluation of the artifact (but even this evaluation was guided by the publicized rubric). The remaining 75% of the grade was determine from individually completed assignments (nine homework assignments, two smaller projects and two closed book exams) which addressed various aspects of the design process. The grades were about one letter grade higher (3.37/4.0 compared to 2.47/4.0 or B+ compared to C+) for the team project compared to the individual work.


## Introduction

Design is, at least in part, a creative process, and its evaluation can be highly subjective. However, all design requires a fundamental skill set ranging from a keen eye for form and color and the manual skills associated with producing images in two and three dimensions for the studio artist to a strong set of analysis tools, a knowledge of materials, and an understanding of manufacturability, standards, team-work, soft constraints and budget for the engineer. For both the studio artist and the engineer, the artifact produced is all that matters in practice. However, in an academic setting, it is the design process that is being taught. Therefore, it is the process, along with the artifact produced, that should be evaluated. Students also benefit more when their process is evaluated since they understand more precisely how to improve. Evaluation of the process tends to be more objective compared to the artifact assessment which may be associated with the failure of a component or a subjective comment from the instructor. This paper describes projects/assignments given to individuals and teams in the first of two courses that focus on design in our curriculum.

Our BSME program requires two "design" courses: a three-hour sophomore course (two-hour lecture and three-hour studio each week) and a three-hour senior (capstone design) course (two three-hour studios each week).. The major products from both courses are team-produced "design solutions". The evaluation of a design solution is difficult, subjective and sometimes controversial as noted above. Further, assessing individual credit for a team-produced artifact is also difficult. To reduce student anxiety from what they may consider subjective faculty evaluation, the grading in both courses has been established to emphasize individual work and the team design process rather than only the team-produced artifact and its performance.

The objectives of the two courses are different. The sophomore course presents an introduction to the design process. Even though there is an artifact produced by each four-person team that is tested in a public competition and evaluated by the instructor, the grading emphasis for the individuals is heavily weighted toward their understanding of the design process. As a result, the team project represents only 20 to 30% of the individual grade (varies semester to semester) and only about 50% of the team project grade is assigned to the performance and evaluation of the artifact itself. In the senior course the satisfactory completion of a project proposed by a “client” (industry or faculty) is the primary focus of the assessment process. Approximately 80% of the individual course grade is associated with the project, but not all students on a given team receive the same grade for their team project since some of the activities associated with the team project are assigned directly to individuals for which they receive individual grades. See Reference 1 for more details on assessment in the senior design course.

In the sophomore course the design solution is an artifact that performs a specified task, e.g., sorts ping pong balls from golf balls, launches various items into or onto various targets, performs one or more functions on a timed basis, uses solar energy to distill salty water, etc. (Reference 2 provides more information on the recent projects assigned in this course.) As noted above, the team project counts for about a fourth of the grade, and peer evaluations[3] are used to aid in the assignment of individual contributions. Usually two smaller individual “design” projects (or one individual and an additional team project) are assigned (for about a fourth of the grade) which are largely “technical communications” assignments. In addition, there is considerable “content” to the class (Personality and Teaming Issues, Intellectual Property, Technical Communications, Writing Specifications, Engineering Ethics, Engineering Economics, Codes and Standards, the Design Process, and Sustainability) which results in nine individual homework assignments (about one sixth of the grade) and two exams (about one third of the grade).

Detailed descriptions of the projects and assignments for the sophomore design course and their assessment in Fall 2007 will now be presented along with results from student surveys in the course.

**Assignments for the Sophomore Design Course**

In the fall 2007, 70 students enrolled in the sophomore design course, MECE 2361. By the time teams were self-selected for the team project during the fourth week, two students had dropped. The remaining 68 students completed the course. The “general” assignments for the course were summarized above. Table 1 lists the specific assignments for fall 2007 which are typical. Some semesters the Team Project may count more when only one individual project is given. Sometimes two team projects and only one individual project are given. Improved technical communication is considered a major objective of the course. All grading was done by the instructor. The projects and most of the homework were graded for content as well as document format and quality of writing.

Table 1: Assignments for MECE 2361 for Fall 2007

| | |
|---|---|
| 10% | 1. Individual Project #1: Two Concepts for the Team Project (Draft Sept 10th, Final Sept 24th) |
| 15% | 2. Individual Project #2: Backyard Play Center (due by 12 noon Nov 30th) |
| 15% | 3. Homework:<br>• a. Student information: 1.0% (due Aug 22nd)<br>• b. Resume: 1.0% (due Aug 27th)<br>• c. Personality and demographic data: 0.5 % (due Sept 17th, in class assignment)<br>• d. Intellectual Property and Codes & Standards: 2.0 % (due Oct 1st)<br>• e. Specifications: 3.5% (due Oct 22nd)<br>• f. Ethics: 1.5% (due Oct 29th)<br>• g. Economics (problems): 2.0% (due Nov 5th)<br>• h. Design Constraints: 2.0% (due Nov 12th)<br>• i. Be Green: 1.5% (due Nov 28th) |
| 25% | 4. Team Project (based on project and peer evaluations)<br>• Initial Testing: Oct 8th<br>• Final Testing and Artifact Evaluation: Oct 31st<br>• Team Presentation: Nov 7th<br>• Team Final Report and Extended Abstract: Nov 19th |
| 12% | 5. Midterm exam (closed book), Oct 15th |
| 23% | 6. Final Exam (closed book), Dec 12th |

Team Project

The largest single component of the grade is the grade for the Team Project. A summarized problem statement (The actual problem description is usually seven or eight pages.) for the Fall 2007 team project is presented in Table 2. All elements of the project are submitted by the team, not by individuals as in the capstone course. Students self-select into teams of four (to the extent possible). The major deliverables for the project are: a final report, a presentation, an extended abstract, a successful Initial Testing, a successful Final Testing, and a functioning artifact for evaluation. An Initial Testing requirement is imposed with a reduced set of requirements. Initial Testing is on a pass/fail basis, and teams unsuccessful would normally meet individually with the instructor to demonstrate a successful device (for reduced credit) within the next week. (All teams in Fall 2007 were successful in the Initial Testing.) Failure to produce a successful Initial Testing would disqualify the team for the Final Testing. The Final Testing is performed in a public venue (usually the lobby of the Engineering Building). There is both a minimum performance requirement and a goal to maximize a figure of merit. The grade for Final Testing is based solely on the figure of merit, once the minimum performance requirement is met. Teams present their devices for an Artifact Evaluation immediately after the Final Testing. The instructor evaluates the artifacts according to an advertised rubric based on the specifications and requirements for the project. The grading rubric is used in an attempt to “quantify” the more “qualitative”

Table 2: Summary of the Problem Statement for Team Project in MECE 2361 for fall 2007

Design and fabricate a device that will "propel" two different types of balls: a golf ball and a ping pong ball, a distance of about five feet such that the balls land as close to the center of a horizontal target as possible. The target will be provided by the instructor and will be available for inspection in class at selected times, but shall not be available for team "practice." All other materials and the balls are to be provided by the design team. The device shall weigh less than ten pounds (the lighter the better for the Final Testing). The target will be placed on the floor, but the device may be either placed on the floor or on the table normally available in the classroom. The device may be placed as far from the target as desired, behind the "five-foot" line. There is no restriction on the type of energy used, but there can be no external energy source, i.e., the energy source is part of the device. Designs using gravitational energy will be viewed more favorably than those using other forms of energy. Teams must surrender their devices immediately after the Final Testing for evaluation. Both written and oral reports are required. Further information on the constraints, goals and evaluation processes are given in the complete document.

For the Initial Testing three of five golf balls must be propelled into the target. The requirement for the Final Testing is to propel six of ten golf and ping pong balls (five of each) into the target. The goal is to propel all ten balls into the bullseye at the center of the target using the lightest possible device. Specifically, the goal is to maximize the Figure of Merit, FM, defined as:

$$FM = 5K + 3L + M - 2^N + 3*(10 - \mu)$$

where

K, L, and M are the numbers of times the golf balls or ping pong balls land in the bullseye at the center of the target, the first concentric ring around the bullseye, and the second concentric ring, respectively (Note that $K + L + M \geq 6$),

N is number of times the balls "miss" the target, i.e., fail to land and remain in any of the three target areas ($N \leq 4$; $K + L + M + N = 10$), and

$\mu$ is the weight of the device in pounds ($0 \leq \mu \leq 10.00$).

GRADING FOR TEAM PROJECT

| | points |
|---|---|
| Initial Testing* | 10 |
| Final Testing** | 30 |
| Presentation | 10 |
| Design Evaluation | 25 |
| Final Report and Extended Abstract | 25 |

*A device that is successful in either of its first two attempts at the Initial Testing receives 10 points. Devices successful in their third attempt receive 8 points; in their fourth attempt, 6 points. Devices first successful between October 8th and 15th will receive 3 points.

** For the Final Testing, points awarded will be determined by the following formula:

Testing Points = Figure of Merit + Bonus Points

Bonus points will be awarded to the successful devices as follows:

- The largest values of K and $10 - \mu$: 20 points each
- The next largest values, etc. 16, 12, 8, and 4 point each
- The smallest value of N: 20 points
- The next smallest value, etc.: 16, 12, 8,and 4 points each

aspects of the solution, i.e., the artifact. The rubric serves two primary purposes. First, the rubric helps the instructor by establishing more uniformity for the grading process and by providing the students with more and useful feedback. (The very act of creating the rubric forces the instructor to think about and identify exactly what is expected in the design.) Second, the rubric helps the studente during the design process by providing a framework or "checklist" for the design. The grading rubric for the Fall 2007 project is given in Table 3. An oral presentation and a final report are always required. A poster or extended abstract may also be required. (Only the extended abstract was required in Fall 2007.) About 50% of the project grade is based on the communication elements. During the semester the teams meet with the instructor at least three times to discuss their progress and difficulties, including personal issues.

Table 3: Grading Rubric for the Major Team Project for Fall 2007

- Concept selection (18%): As much as half credit may be lost for using a non-gravity source of energy. As much as half credit may be lost if a device is considered to be too powerful and perhaps representing a danger. Otherwise, the quality of the concept selection, based on its uniqueness and the probability of success will be assessed.
- Creativity in executing the concept (18%): How was the concept implemented? Was it <u>not</u> like everyone else's? Was it likely to work? Did it show good thinking?
- Robustness (18%): Does its operation require special care or could anyone just walk up and operate it? Does it look like it will work for a few days or just during the testing period.
- Craftsmanship and esthetics (18%): How does it look? How much care was exercised to make look good? Does it represent the "spirit" of the team name?
- Attention getting (12%): Did heads turn?
- Sales Brochure (18%): What's the overall quality and content? Does it make good use of graphics and/or photographs?

Individual Projects

The first individual project is usually a proposal (including all the elements of a formal technical report), describing and evaluating at least two concepts suitable for development into a solution for some aspect of the team project, e.g., to satisfy the Initial Testing requirements in Fall 2007. Grading emphasis is placed on the quality of the writing, the report format (A template is given.), and the effectiveness of the descriptions of the concepts. (Acceptable drawings are highly recommended.) As seen in the schedule in Table 1, the proposals are submitted first as a draft (counting 67%) and then, after feedback from the instructor on the individual submissions, as a finished product (33% for improvements made as per the instructor's comments).

The summary problem statement for the second individual project for fall 2007 is given in Table 4.

Table 4: Second Individual Project for MECE 2361:
Detailed Design of a Children's Play Center for Fall 2007

| |
|---|
| Prepare a suitable, do-it-yourself manual for the construction of a children's, backyard, recreation center. The materials, including commercial slides, swings, etc. (but no trampolines), for the center should cost about $1500 at Lowe's or Home Depot. The manual should be directed to a mechanical engineering graduate with a spouse and three children, currently 1, 4, and 7 years old. Safety should be the most important consideration for the construction and use of the center. The safe life expectance of the center is ten to fifteen years, and it should provide an opportunity for entertainment and physical exercise for the indicated children during this time. The space available is approximately 30 feet by 15 feet with an additional 5 feet of grass surrounding the space on all sides. For construction the graduate and spouse will also have the help of a physically active grandfather, age about 60. Assume that the usual hand power tools and hand tools that are familiar to a do-it-yourselfer are already available. The manual is limited to eight pages of double-spaced text (Times New Roman 12), i.e., not including figures, tables, references or appendices. Additional details are given in the complete document. |

Homework

The first three homework assignments are largely survey instruments so we can get to know our students better. Homework 1 is a survey covering the student's personal and academic background and technical skills (software and shop). Homework 2 requests a current resume for which the student is to be applying for a summer internship. The resumes are reviewed and improved as needed. Homework 3 is a demographic survey that includes requests for personal feelings about the design and the class. As part of this survey students also complete a Kiersey Temperament Sorter instrument[4] which is used by the instructor to determine each students Myers-Briggs Temperament Indicators. These results are returned to the students and lead into a discussion of personality and team issues.

The fourth homework assignment (Table 5) followed lectures on intellectual property and code and standards.

A lecture was given on problem definition and target specifications. Target specifications are viewed as the client's instructions to the designer and provide the complete set of "functionalities" with respect to technical (function), ergonomic, economic, and esthetic specifications. The associate homework assignment is given in Table 6.

Table 5: Intellectual Property and Codes and Standards Homework Assignment in MECE 2361 for Fall 2007

| |
|---|
| Make an inventory of five different types of the "appliances" in your home (or any other space containing some appliances, e.g., Lowe's or Home Depot).<br>Record the following information for each as appropriate:<br>• Name and description of the item<br>• Function (if not obvious from name)<br>• Specifications, e.g., voltage, power, heating or cooling capacity, etc.<br>• Company responsible for manufacture and contact information<br>• Place of manufacture<br>• Any patenting information, e.g., a patent number<br>• Any evidence of standards satisfied, e.g., UL (Underwriter's Laboratory) plus the identification (number) of the standard<br>At least two appliances should have patent information and at least two should have evidence of standards satisfied. For the two (or more) with patent information look up the patent on the PTO website or on the Google Patent website. (If the claim is "patent pending" (pat. pend.) look up the final patent number (if it exists) using Google Patent Search). Copy the first page of the patent for your report and then describe what part of the patent claim seems to apply to your particular appliance. For the ones with evidence of satisfying a standard, check the standards organization's (probably UL) website to find out more about the particular standard(s) applied. If no information is found, so indicate in your report. |

Table 6: Specifications Homework Assignment in MECE 2361 for Fall 2007

| |
|---|
| Wishing to expand its product line, Horse&Buggy, Inc., a major manufacturing company which specializes in large transportation related products, has decided to take the giant and risky step of entering the personal vehicle market. Their Director of Innovation has convinced the Board of Directors that Horse&Buggy, Inc. should design and manufacture a completely new, personal, urban, transportation (the PUT) device. Since the company's strength is design and manufacture, not "problem definition", H&B have decided to seek outside help in the initial stages of the design process. Therefore, they have declared an open competition for the best set of specifications for the new device.<br><br>You are anxious to participate in the PUT device project because you believe that urban pollution and inefficient transportation are two of the main problems in urban America and are concerned about the life styles available to your future children and grandchildren. You decide to respond to H&B's challenge and prepare an entry for their competition. Formulate a complete and exhaustive set of specifications, in the "bullet" format, based on your understanding of what the ideal solution should be for this innovative PUT device, considering all constraints and goals imposed on the system , i.e., technical, ergonomic, economic, and esthetic. |

A lecture was given and a discussion was held on engineering ethics and the associated homework assignment is given in Table 7.

Table 7: Engineering Ethics Homework Assignment for MECE 2361 in Fall 2007

| |
|---|
| Imagine that an engineering colleague has been placed a situation in which he or she faces an ethical dilemma and is unclear about how to proceed. In order to help, you decide to research similar situations. Go to the Murdough Center for Engineering Professionalism (http://www.niee.org/pdd.cfm?pt=NIEE&doc=EthicsCases) or to http://www.niee.org and click on "ethics cases' and the "complete set of cases: 76-present". (It is suggested that you use Internet Explorer rather than Netscape Communicator.) Find an ethics case for the time period 1995 to 2000 that interests you (Assume it would also be useful to your colleague.) and write a summary explaining the case to your colleague in order to guide him or her in how to proceed. The summary should be limited to about 300 words and the ethical issues involved should be referenced to the ASME Code of Ethics. |

A lecture on engineering economics was given which discusses the issues related to the time value of money and some example problems are worked. Table 8 lists the associated homework assignment.

Table 8: Engineering Economics Homework Assignment for MECE 2361 in Fall 2007

| |
|---|
| 1. A new widget, with a service life of four years, would save $50,000. in production costs each year. Using a 12.0% annual interest rate, determine the highest price that could be justified for the widget. Lump each year's savings at the end of the year. Work the problem again and take the saving at the end of each month. |
| 2. How soon will your investment double in value if it is invested at 3.50%, and at 8.50%? What annual interest would be required to double your investment in five years. Work these problems first assuming an annual compounding and then a monthly compounding. |
| 3. Acme is selling 8.00%, $1000. bonds for payment in 15.0 years. That is, the bond will pay 8.00% of the principle at the end of each year and then 108% at the end of the $15^{th}$ year. What is the equivalent cost of a 10.00% bond under the same conditions, i.e., how much would you have to pay (present value) for a 10.00% bond that provides the same income as the 8.00% bond? Assume the interest is determined only at the end of each year. |
| 4. When you buy your new car, you are offered a $1,000 maintenance contract that will cover all repair costs for five years on the car. You estimate the following repair expenses for the car: Year 1: $0; Year 2: $100; Year 3: $250; Year 4: $500; Year 5: $750. If you could also make an investment with an 8.00% return for five years, would you buy the maintenance contract or invest your money? |
| 5. Suppose you are selecting a new central AC unit for a house with a design cooling load of 36 kBtu/hr. The lowest priced system ($2,000) has an SEER (seasonal energy-efficiency ratio) of 10 Btu/W-h, i.e., 10.0 Btu of cooling for each W-h of electrical energy input. Two other systems (at $2,500 and $3,100) have SEERs of 12.0 and 14.0, respectively. Local electricity rates are currently $0.10/kWh and expected to increase at the rate of 5% a year. The current interest rate is 8% for home improvements. Perform a LCC analysis for the three systems assuming a 15-life and equal maintenance costs. Assume the AC systems will operate for 1500 hours a year. |

Lectures on design constraints and sustainability were given, and the two homework assignments listed in Tables 9 and 10 were given.

Table 9: Design Constraints Homework Assignment for MECE 2361 in Fall 2007

Design is the process of creating and fabricating artifacts to meet desired needs within realistic constraints. In the classroom these constraints are usually limited to the properties (or physical, chemical, electrical, thermal, etc. characteristics) of the materials and the requirements of the design space (physical size, availability of materials, economics, useful product life, manufacturability, etc.). However, there are usually other, sometimes called "soft", constraints which should be considered in the design process. These soft constraints include

- Environmental factors (for producing the raw materials, for producing the artifact itself, or from the use of the artifact),
- Social factors (e.g., displacement of homes, towns, cultures, etc.),
- Political factors (negative and positive effects of governmental action and inaction),
- Ethical factors (the individual's desire to do the "right thing", e.g., avoid the dumping of toxic waste even though there may be no applicable laws involved or immediate issue),
- Health and safety factors (avoid any adverse effects on workers, consumers and the public due to the production or use of the artifact), and
- Sustainability (avoid making decisions today that will limit the options of future generations).

Check newspapers or their internet equivalents for articles related to how these soft constraints were or were not applied to a design process. Select two of these articles related to different soft constraints (as defined above). Write 100- to 200-word explanations of how the "soft" design constraints were or were not applied and attach a copy of each article.

Table 10: Be Green Homework Assignment for MECE 2361 in Fall 2007

There are simple things all of us can do in our everyday life to reduce the level of carbon dioxide emissions and other greenhouse gas (GHG) emissions that we are directly and indirectly responsible for (our carbon footprint). The http://www.begreennow.com/ website offers users the opportunity to determine their own carbon footprint and offers suggestions for reducing it. Login to the BeGreen Portal and click on to "carbon calculator". Determine the effects of your household and travel related energy use. Write a short report (less than 400 words) addressed to one of your engineering student colleagues describing

- the global warming issue in a technical sense,
- how human activity may be contributing to this undesirable global effect,
- what could be done on a global scale to reduce any undesirable effect, and
- your personal carbon footprint (as determined from the "carbon calculator").

**Assessment for the Sophomore Design Class**

Team Project

As noted above, the major deliverables for the project are usually: the results of Final and Initial Testing, the instructor's evaluation of the artifact, and the reports (progress reports (not required in Fall 2007), a final report, a presentation, poster and/or extended abstract). The grading for the Fall 2007 team design project is given in:

- Table 11: Figure of Merit plus the Bonus Points associated with the Final Testing,
- Table 12: Instructor's Evaluation of the Artifact, and
- Table 13: Summary of Grading for Team Project.

Table 11: Figure of Merit Plus Bonus Points Results for Fall 2007 Team Project

| Team | Trial[1] | $\mu$[2] | K[3] | L[4] | M[5] | N[6] | ˜ FM[7] | B[8] | T[9] | Gr[10] |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 7.00 | 2 | 3 | 1 | 3 | 24.0 | 0 | 24.0 | 1.76 |
| 2 | 2 | 2.20 | 5 | 5 | 0 | 0 | 62.4 | 14 | 76.4 | 3.86 |
| 3 | 2 | 6.50 | 4 | 6 | 0 | 0 | 47.5 | 8 | 55.5 | 3.02 |
| 4 | 2 | 1.44 | 4 | 4 | 1 | 1 | 56.7 | 12 | 68.9 | 3.55 |
| 5 | 2 | 0.94 | 6 | 4 | 0 | 0 | 68.2 | 42 | 110.0 | 5.21* |
| 6 | 1 | 2.94 | 5 | 5 | 0 | 0 | 60.2 | 14 | 74.2 | 3.77 |
| 7 | 1 | 5.38 | 3 | 7 | 0 | 0 | 48.9 | 8 | 56.9 | 3.08 |
| 8 | 2 | 6.38 | 0 | 3 | 7 | 0 | 25.9 | 8 | 33.9 | 2.16 |
| 9 | 1 | 1.88 | 0 | 7 | 2 | 1 | 45.4 | 0 | 45.4 | 2.62 |
| 10 | 1 | 5.75 | 1 | 3 | 5 | 1 | 29.8 | 0 | 29.8 | 1.99 |
| 11 | 1 | 0.75 | 5 | 3 | 2 | 0 | 62.8 | 26 | 88.8 | 4.35* |
| 12 | 2 | 4.50 | 5 | 4 | 0 | 1 | 51.5 | 6 | 57.5 | 3.10 |
| 13 | 1 | 5.68 | 1 | 3 | 6 | 0 | 32.1 | 8 | 40.2 | 2.41 |
| 14 | 1 | 1.94 | 2 | 3 | 3 | 2 | 42.2 | 4 | 46.2 | 2.65 |
| 15 | 2 | 3.81 | 6 | 2 | 1 | 1 | 53.6 | 18 | 71.6 | 3.66 |
| 16 | 1 | 4.62 | 3 | 7 | 0 | 0 | 51.1 | 8 | 59.1 | 3.17 |
| 17 | 2 | 1.56 | 0 | 5 | 2 | 3 | 34.3 | 8 | 42.3 | 2.49 |
| Avg | | 3.72 | 3.1 | 4.4 | 1.8 | 0.8 | 46.9 | 10.6 | 57.5 | 3.11 |

[1] first or second run
[2] $\mu$ is the weight of the device in pounds ( $\mu \leq 10.0$),
[3] K is the number of balls striking the bullseye,
[4] L is the number of balls in the next ring.
[5] M is the number of balls in outer ring
[6] N is the number balls missing the target
[7] FM is the calculated figure of merit: $FM = 5K + 3L + M - 2^N + 3*(10 - \mu)$ (See Table 2)
[8] B are bonus points (See Table 2)
[9] T is the total points for Final Testing (FM+B)
[10] Grade for Final Testing (on the 4.0 scale)
* Extra points carry over to other components of the Team Project

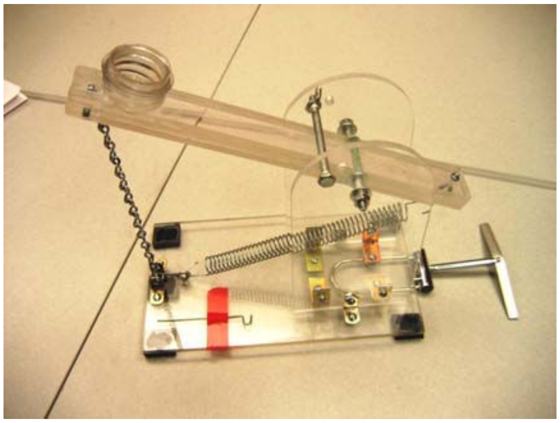
Pictures of some of the artifacts are shown in Figs. 1 through 8. The artifact type and test results are summarized in Table 14.

Twelve of the seventeen teams built gravity-driven artifacts; four used metal springs; and one used a bungy cord. The artifact built by Team 15 (left side of Fig. 4) was constructed completely from fiberglass (except for the bounce plate) which one of the team members modeled himself from fiberglass sheets. The artifact from Team 13 (Fig. 7) had the most advanced design: the gravity-driven, constant-velocity anvil.

Table 12: Instructor Evaluation of Artifact for Fall 2007 Team Project

| Team | Con[1] | Cre[2] | Rob[3] | Est[4] | Att[5] | SB[6] | Tot[7] | Gr[8] |
|---|---|---|---|---|---|---|---|---|
| max | 15 | 15 | 15 | 15 | 10 | 15 | 85 | |
| 1 | 11 | 10 | 4 | 2 | 7 | 5 | 39 | 2.08 |
| 2 | 7 | 14 | 14 | 13 | 10 | 18* | 76 | 4.05 |
| 3 | 13 | 10 | 12 | 8 | 7 | 15 | 65 | 3.47 |
| 4 | 15 | 12 | 14 | 9 | 7 | 8 | 65 | 3.47 |
| 5 | 7 | 10 | 15 | 8 | 5 | 15 | 60 | 3.20 |
| 6 | 7 | 13 | 14 | 13 | 7 | 10 | 64 | 3.41 |
| 7 | 13 | 12 | 14 | 14 | 10 | 8 | 71 | 3.79 |
| 8 | 13 | 10 | 8 | 14 | 6 | 12 | 63 | 3.36 |
| 9 | 13 | 8 | 4 | 5 | 7 | 7 | 44 | 2.35 |
| 10 | 13 | 14 | 8 | 13 | 7 | 3 | 58 | 3.09 |
| 11 | 15 | 14 | 13 | 13 | 7 | 15 | 77 | 4.11 |
| 12 | 13 | 8 | 10 | 7 | 5 | 9 | 52 | 2.77 |
| 13 | 12 | 15 | 8 | 11 | 10 | 10 | 66 | 3.52 |
| 14 | 7 | 5 | 5 | 7 | 6 | 3 | 33 | 1.76 |
| 15 | 14 | 15 | 11 | 14 | 10 | 13 | 77 | 4.11 |
| 16 | 12 | 15 | 11 | 13 | 8 | 8 | 67 | 3.57 |
| 17 | 7 | 11 | 6 | 12 | 7 | 18* | 61 | 3.25 |

[1] Concept Selection: gravity preferred; difference from others in similar category
[2] Creativity: creativity demonstrated in applying the concept selected
[3] Robustness: confidence that device will continue to function
[4] Esthetics: spirit and craftsmanship
[5] Attention getting: was audience interested?
[6] Sales Brochure: operating instructions and description
[7] Total points: sum of the above 6 items
[8] Grade for artifact evaluation (on the 4.0 scale) based on 75 points, i.e., 10 bonus points for all
*extra credit



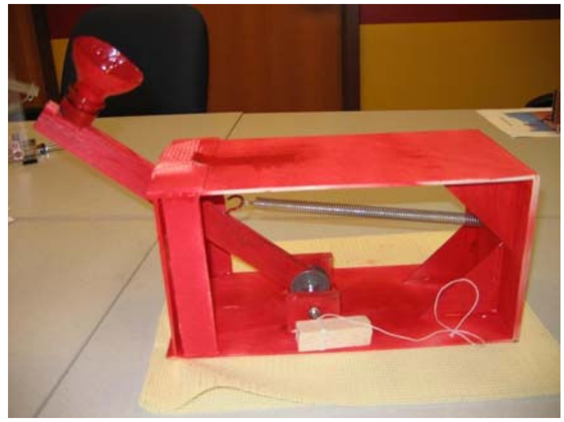


Figure 1: Team 2

Figure 2: Team 5

Figure 3: Team 6

Figure 4: Teams 15 & 7

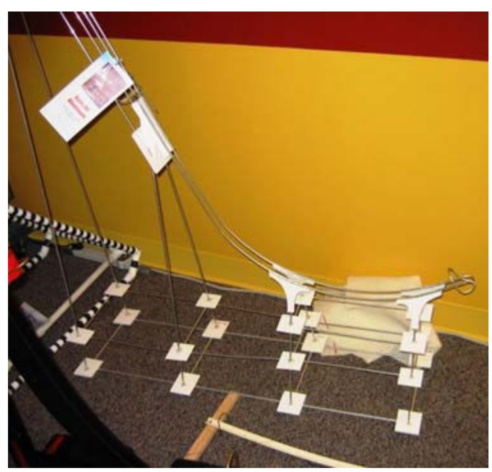



Figure 5: Team 8

Figure 6: Team 11

Fig. 7: Team 13

Fig. 8: Team 16

Table 13: Final Grading for Project

| Team | FTest[1] | Eval[2] | ITest[3] | Oral[4] | Writ[5] | Gr[6] |
|---|---|---|---|---|---|---|
| | 25% | 30% | 10% | 10% | 25% | 100% |
| max | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 1 | 1.76 | 2.08 | 4.0 | 1.0 | 2.8 | 2.25 |
| 2 | 3.86 | 4.05 | 4.0 | 2.7 | 4.0 | 3.84 |
| 3 | 3.02 | 3.47 | 4.0 | 3.3 | 4.0 | 3.51 |
| 4 | 3.55 | 3.47 | 4.0 | 3.0 | 3.6 | 3.53 |
| 5 | 5.21 | 3.20 | 4.0 | 3.7 | 4.0 | 4.13 |
| 6 | 3.77 | 3.41 | 4.0 | 3.0 | 4.0 | 3.85 |
| 7 | 3.08 | 3.79 | 4.0 | 3.0 | 2.7 | 3.24 |
| 8 | 2.16 | 3.36 | 4.0 | 2.5 | 4.0 | 3.14 |
| 9 | 2.62 | 2.35 | 4.0 | 2.5 | 3.1 | 2.80 |
| 10 | 1.99 | 3.09 | 4.0 | 3.7 | 4.0 | 3.14 |
| 11 | 4.35 | 4.11 | 4.0 | 3.7 | 4.0 | 4.19 |
| 12 | 3.10 | 2.77 | 4.0 | 3.0 | 2.8 | 3.02 |
| 13 | 2.41 | 3.52 | 4.0 | 4.0 | 2.7 | 3.08 |
| 14 | 2.65 | 1.76 | 4.0 | 4.0 | 3.0 | 2.79 |
| 15 | 3.66 | 4.11 | 4.0 | 4.0 | 3.8 | 3.91 |
| 16 | 3.17 | 3.57 | 4.0 | 3.8 | 3.9 | 3.62 |
| 17 | 2.49 | 3.25 | 4.0 | 3.3 | 4.0 | 3.29 |
| **avg** | 3.26 | 3.16 | 4.0 | 3.2 | 3.6 | 3.37 |

[1] Final Testing
[2] Instructor Evaluation
[3] Initial Testing
[4] Team Final Oral Report
[5] All Written Reports

Table 14: Summary of Devices and Performances

| Team | Artifact Type | Motive | Materials | Test Notes | Grade |
|---|---|---|---|---|---|
| 1 | trebuchet | gravity | wood | lowest FoM | C- |
| 2 | spring/lever | spring | mostly plastic | 10 for 10 | A |
| 3 | pendulum | gravity | PVC | 10 for 10 | B |
| 4 | pendulum | gravity | wood | | A- |
| 5 | spring/lever | spring | wood | highest FoM | A+ |
| 6 | spring/lever | spring | wood | 10 for 10 | A |
| 7 | drop/bounce | gravity | metal | 10 for 10 | B |
| 8 | pendulum | gravity | wood | 10 for 10 | C |
| 9 | ramp | gravity | plastic/cardboard | | B- |
| 10 | ramp | gravity | wood | | C |
| 11 | ramp | gravity | aluminum/ museum board | lightest; 10 for 10 | A+ |
| 12 | pendulum | gravity | wood | | B |
| 13 | spinning anvil | gravity | various; hand made parts | 10 for 10 | C+ |
| 14 | bungy cord catapult | rubber | wood | | B- |
| 15 | drop/bounce | gravity | fiberglass/ metal | 6 bullseye | A- |
| 16 | drop weight catapult | gravity | wood/PVC | 10 for 10 | B+ |
| 17 | spring catapult | spring | wood | | C+ |

Individual Assignments

Table 15 summarized the grades for the individual assignments.

Course Grades

The average grade for individual work was 2.47 (out of 4.0) as seen in Table 15, near the bottom of column 4. The average grade for the team work was 3.37 as seen in Table 13, last column, last row. The resulting average grade for the course was 2.69 ± 0.65 (a B-) which includes the team grade reductions for the four students penalized though the peer evaluations. (Three students' team grades were reduced by 15%; one, by 30%.) The distribution of the final course grades is given in Table 16.

**Student Feedback**

End-of-the-semester surveys are given every semester in the course. Some of the questions/statements change, but there remains a core set. Table 17 lists responses to seven of the core statements for the five semesters from Fall 2002 through Fall 2005. These are generally very positive response with only about 2% of the students feeling that they did not improve their abilities in designing, teaming and communicating, and about 4% "not enjoying" several aspects of the project work. Table 18 provides responses to the same core statements for the Fall 2007 as well as to some additional responses. The Fall 2007 responses are very close to the previous average responses with the "ability" statements rated a little lower and the "enjoy" statements a little higher. From the last six statements for the Fall 2007 thirteen per cent of the students indicated the course was not useful or that they didn't learn a lot. Only two of sixty didn't like the peer evaluations. Less than 10% indicated that their teaming experience was not good. By the last two statements, it is clear that, despite some complaints about our emphasizing writing too much in the course, student do recognize the importance of teaming and writing skills for their careers.

Table 15: Summary of Grades for Individual Assignments

| Ind. Assign | Type | %[1] | Avg.[2] | SD[3] | Miss[4] |
|---|---|---|---|---|---|
| HW#1 | survey | 1.0 | 4.0 | 0 | 0 |
| HW#2 | resume | 1.0 | 4.0 | 0 | 0 |
| HW#3 | demo | 0.5 | 3.82 | 0.83 | 3 |
| HW#4 | IP & C&S | 2.0 | 3.51 | 1.24 | 6 |
| HW#5 | specs | 3.5 | 2.43 | 1.15 | 7 |
| HW#6 | ethics | 1.5 | 2.93 | 1.35 | 11 |
| HW#7 | economics | 2.0 | 1.82 | 1.24 | 13 |
| HW#8 | design | 2.0 | 3.16 | 1.59 | 14 |
| HW#9 | be green | 1.5 | 1.48 | 1.48 | 14 |
| HW avg. | | | 2.92 | | 68* |
| | | | | | |
| Project #1 | concepts | | | | |
| draft | | 6.7 | 2.74 | 1.04 | 0 |
| Final | | 3.3 | 3.45 | 0.71 | 0 |
| Project #2 | play center | 15.0 | 3.12 | 1.04 | 3 |
| | | | | | |
| Exam #1 | closed book | 12 | 2.02 | 1.42 | 0 |
| Exam #2 | closed book | 23 | 1.75 | 1.11 | 0 |
| | | | | | |
| Total/Average | | 75 | 2.47 | | |
| Peer | evaluations | | 0.989 | 0.047 | 4 students penalized |

[1] per cent of course grade
[2] average grade based on a 4.0 scale (4=A; 3=B; 2=C; 1=D; 0=F)
[3] standard deviation of grade distribution
[4] number of assignments not submitted (class of 68); missing grades averaged in as zeros.
* 17 of the 68 missing assignments were attributed to 3 students

Table 16: Course Grades for Fall 2007

| Grade | A | A- | B+ | B | B- | C+ | C | C- | D+ | D |
|---|---|---|---|---|---|---|---|---|---|---|
| # | 3 | 6 | 6 | 26 | 12 | 4 | 5 | 1 | 0 | 5 |

Table 17: Results from End-of-the-Semester Class Survey (Fall 2002 through Fall 2005) (5 indicates the students “strongly agree” with the statement; 4 indicates, “agree”; 3 indicates, “neither agree nor disagree”; 2 indicates, “disagree”; and 1 indicates, “strongly disagree”; N is the number of responses; and “avg” is the average of the responses.

| 1 | 2 | 3 | 4 | 5 | N | avg | I feel that I improved my ability to |
|---|---|---|---|---|---|---|---|
| | | | 140 | 132 | 300 | 4.31 | design a system or component to meet desired needs |
| | 9 | 31 | 129 | 131 | 300 | 4.27 | function on a team |
| 1 | 11 | 57 | 143 | 88 | 300 | 4.02 | communicate effectively |
| | | | | | | | |
| | | | | | | | I enjoyed |
| 3 | 7 | 22 | 99 | 169 | 300 | 4.41 | working on the projects |
| 8 | 11 | 35 | 99 | 147 | 300 | 4.22 | working on a team |
| 1 | 13 | 31 | 94 | 161 | 300 | 4.34 | having friendly competition between teams |
| 2 | 6 | 30 | 85 | 177 | 300 | 4.43 | seeing how others solved problems I struggled with |

Table 18: Results from End-of-the-Semester Class Survey for Fall 2007 (5 indicates the students “strongly agree” with the statement; 4 indicates, “agree”; 3 indicates, “neither agree nor disagree”; 2 indicates, “disagree”; and 1 indicates, “strongly disagree”; N is the number of responses; and “avg” is the average of the responses. (Some students did not respond to all the statements, and some students did not complete the survey so all their results are not included.)

| 1 | 2 | 3 | 4 | 5 | N | avg | I feel that I improved my ability to |
|---|---|---|---|---|---|---|---|
| | 1 | 8 | 25 | 21 | 55 | 4.20 | design a system or component to meet desired needs |
| | 1 | 10 | 20 | 24 | 55 | 4.22 | function on a team |
| | 1 | 13 | 23 | 18 | 55 | 4.05 | communicate effectively |
| | | | | | | | |
| | | | | | | | I enjoyed |
| | 1 | 1 | 19 | 36 | 57 | 4.58 | working on the projects |
| 1 | 11 | 4 | 19 | 33 | 57 | 4.46 | working on a team |
| 1 | 1 | 7 | 16 | 33 | 58 | 4.36 | having friendly competition between teams |
| | 2 | 6 | 15 | 33 | 56 | 4.41 | seeing how others solved problems I struggled with |
| | | | | | | | |
| 2 | 4 | 14 | 25 | 15 | 60 | 3.78 | I thought this was a useful engineering course |
| 2 | 8 | 10 | 28 | 12 | 60 | 3.67 | I learned a lot from the course |
| | 2 | 12 | 21 | 25 | 60 | 4.15 | I like the peer evaluation of team members |
| 36 | 14 | 5 | 4 | 1 | 60 | 1.67 | My experience on my team was not good |
| | | 4 | 9 | 46 | 59 | 4.71 | Teaming skills will be important in my career |
| 1 | | 4 | 11 | 43 | 59 | 4.61 | Tech Com skills will be important in my career |

## Conclusions

This paper has presented summarized versions of the assignments in an introductory design class offered in the fall of 2007 and completed by 68 students. Twenty-five per cent of the course grade was determined from team performances on a two-month long design, fabricate and test project. Seventy-five per cent of the grade was determine from individually completed assignments (nine homework assignments, two smaller projects and two exams). The grades were about one letter grade higher (3.37/4.0 compared to 2.47/4.0 or B+ compared to C+) for the team project compared to the individual work. The average grade for the course was 2.69/4.0 or a B-. Students recognize the importance of teaming and writing in the design process and most enjoy working on projects in teams.

## Bibliography


1. Richard Bannerot, Ross Kastor, and Paul Ruchhoeft, "Interdisciplinary Capstone Design at the University of Houston", Proceedings for the Capstone Design Course Conference - 2007, June 13-15, 2007, Boulder, CO. Also submitted to Advances in Engineering Education.
2. Richard Bannerot, "Hands-on Projects in an Early Design Course," accepted for presentation at the 2008 ASEE Annual Conference and Exposition, Pittsburgh, PA, June 22-25, 2008.
3. R. W. Brown, "Autorating: Getting Individual Marks from Team Marks and Enhancing Teamwork," 1995 Frontiers in Education Conference Proceedings, Atlanta, GA, November 2-4, 1995, available at http://fie.engrng.pitt.edu/fie95/3c2/3c24/3c24.htm
4. David Kiersey and Marilyn Bates, Please Understand Me – Character and Temperament Types Prometheus Book Company, Del Mar, CA, 1984.