AC 2010-1642: THE CHALLENGE OF CONSISTENT GRADING IN REAL WORLD, OPEN ENDED DESIGN WITH MULTIPLE AND MULTI-DISCIPLINARY INSTRUCTION

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Abstract

The S_______ School of Engineering at the University of C____ admits ~730 first year students each fall; these students are required to take a 'Common Core' program for their first year before choosing their field of engineering. As part of the Common Core year, all students take two half courses in Design and Communication. These two courses (ENGG 251 and ENGG 253) are interdisciplinary courses: the teaching team consists of engineers from all disciplines represented at the university (mechanical, electrical, etc); a fine arts instructor, specializing in drawing and sketching; and a technical writing instructor, specializing in written and oral communication. The 251/253 courses are project-based; students work in small groups on real world problems, are required to sketch and document their work and to write formal reports on their projects.

While the 251/253 courses present a number of challenges to the instructional team, including the logistics of managing ~730 students and 30 Teaching Assistants, planning five new and unique projects for each academic year and integrating community groups into real-world scenarios, the largest challenge facing the team is that of consistency of assignment design and evaluation.

This paper will describe a methodology for maintaining instructional and grading consistency across the many layers of student/tutorial assistant/instructor interaction.

Due to the scope of the course, each of the five projects is developed by one or more instructors, with each of the 9 instructors contributing to at least one project. As the instructors come from a variety of backgrounds, consistency has been problematic – what one instructor considers complete assignment information, another considers either woefully inadequate or more detailed than necessary. In addition, as the course is project-based, there are no 'right' answers, only ones that are workable and ones that are not. To further complicate matters, the course emphasizes the design process, so that a group that had excellent process but did not fully succeed at the challenge can still receive an above average grade.

Over the last two years, the instructor team has embarked on a new path to ensure consistent and effective assignment design and evaluation. This path, which takes advantage of the team's interdisciplinary strengths, has resulted in a 150% increase in student satisfaction with the course, based on the student rating questionnaires, and has reduces student appeals for remarking by 50%.

By standardizing assignment design, allowing for team feedback before assignments are distributed, ensuring consistent updates on project development and providing clearly evaluated exemplars for T.A.s, the instructor team has not only increased student satisfaction, they have ensured a more reliable educational experience for the students, leading to greater student commitment and engagement.

Introduction

As engineering education moves away from traditional book-based instruction towards real-world problem-based learning, it remains necessary to ensure that academic standards and practices are still observed. One of the greatest challenges for instructors looking to move towards problem-based learning is the issue of course structure and evaluation. How can work that is by its very nature flexible and open-ended be evaluated consistently? In addition, what happens when multiple subjects are integrated into a course? While work has been done on integrating technical communications into engineering[1], very little literature exists on multiple-subject integration. Over the past 8 years, our team has worked to develop a strong curriculum[2- 6] which successfully integrates the multiple skill-sets required for communications, fine arts and engineering design; however, the challenge remains to develop appropriate and effective evaluation methods. Working from current literature on rubrics[7-12], as well as more recent work on evaluation strategies [13, 14], a custom approach has been developed, one that has shown clear and measureable improvements in both consistency of evaluation and student satisfaction.

ENGG 251/253 are paired first year courses offered at the S___ School of Engineering at the University of C____. S____ has a common core first year program, which ensures that all students have the same background, and allows students a full year to adjust to the University and to gather some information about the various areas of engineering offered at the school before they have to specialize. ENGG 251 and 253 are key components of this first year program, offering students education in Engineering Design and problem solving, as well as instruction in drawing, sketching, technical writing and presentation skills.

Course Structure

Because of the broad and varied curriculum of ENGG 251/253, a traditional lecture/lab structure is not truly practical. Instead, 251/253 rely on long and intensive lab periods 94.5 hours a week, divided into two blocks, one of 1.5 hrs and one of 3 hrs) with short lectures (1 hr. per week). In addition, the course work is divided into projects or ‘challenges’, with students working on three challenges in the fall semester (251) and two challenges in the winter semester (253). Students work in groups for all challenges, with less than 50% of their course marks coming from individual assignments (43%).

As ENGG 251/253 are first year courses, students enter with minimal knowledge of the design process; in addition, most have little to no experience with sketching and often have negative associations with written and oral communication assignments as well as group work. In order to ensure student success, the challenges are designed to build skills in all these areas, with each challenge growing in scope and scale.

One of the challenges of developing a project course is the need to constantly develop new projects. Experience has shown that if exactly the same projects are repeated from year to year with no changes, the first year sees a multitude of possible solutions, while the second year sees endless versions of the one or two solutions that scored highly the year before. As the design process, and the problem-solving skills related to that process, is the ultimate goal of the course, this is clearly not an ideal situation. Thus, 4 new projects are developed every year; only the 'Rube Goldberg Challenge' is technically repeated, although each year sees new requirements, technical challenges and limitations imposed on the construction of the machine [15-23].

Obviously, creating entirely new challenges every year presents a tremendous preparation challenge. In the first years of the course, the instructional team was stable, allowing for intense preparation of challenges in the summer. As the course has grown, so too has the instructional team. In order to allow instructors creative control over challenges without having to re-invent the wheel, general categories of challenges have been developed. Thus, while each challenge is new each year, they fit into a structure that allows for maximum skill development. The current structure is as follows:

ENGG 251 (Fall semester)

1) The MindStorms Challenge: A perennial introductory challenge, a project based around the LEGO MindStorms robotic kit provides an engaging introduction to engineering design. Lasting three weeks, the MindStorms challenge introduces students to the 'design, test, repeat' nature of engineering, as well as basic 2D sketching and introductory documentation and report writing. This challenge usually runs for the first three weeks of the year. Previous challenges have included Space Elevators, Robotic Hands and Lifting Devices and the ever-popular Predator and Prey evasion robots.

2) Materials and Construction Challenge: Another three week challenge, Materials and Construction asks students to investigate the roles of materials in engineering design. Students are asked to deconstruct a device or object, to test the materials used in construction of the device/object and to investigate whether these materials could be upgraded or altered to improve performance. This challenge also serves as an introduction to isometric sketching, as well as introducing refinements to the reporting process. Some of the objects investigated include: shoes, skates, engine parts, and, most recently, disposable cameras.

3) The Social Awareness Challenge: A six week challenge that covers the second half of the semester, the SA Challenge introduces students to research techniques, long-term planning and the idea that engineering can be used to solve all types of problems. This challenge is usually done in partnership with a campus organization or group that encourages innovative engineering. Previous

challenges have included Solar Car development, development of materials for the Solar Decathlon house team and product development for Engineers without Borders.

ENGG 253

1) The Rube Goldberg Challenge: The only challenge to be repeated every year, the Rube Goldberg Challenge is often the most popular challenge of the year. Serving as an introduction to both multi-group work (seven teams of four collaborate on a single machine) and project management, students have five weeks to construct a minimum 27 step Rube Goldberg Machine. New mandatory end-steps, as well as a list of forbidden themes, are released each year to ensure that previous designs are not copied directly.

2) The Partnership Challenge: The final challenge of the year, the Partnership Challenge runs for seven to eight weeks, and is the culmination of all the course work. The course partners with a company or non-profit organization which provides a real-world problem for the students to work on. Previous partners have included A___Children's Hospital, C_______ Heart and Stroke Foundation, Speedskating C_____, The C____ Homeless Foundation and The Mustard Seed, a C____ Homeless Shelter.

The broad nature of the course, as exemplified by the challenges, extends to the teaching team as well. The course currently has a 'Head Instructor' who oversees the entire program; six engineering instructors, representing all five major branches of engineering offered at S______ (Mechanical, Chemical and Petroleum, Civil, Electrical and Computer and Geomatics), who supervise the individual lab sections; a fine arts instructor and a communications instructor; in addition, the course also has a full time technician, 20-24 engineering teaching assistants, 4-8 fine arts/industrial design teaching assistants and 4-6 communications teaching assistants.

As one might expect, even with the above challenge framework, asking a teaching team of 9 to develop four new projects (two in partnership with outside organizations) every year can be a complicated undertaking. Over the past two years, the course has developed a comprehensive method of developing, executing and evaluating projects that not only leads to consistent assignment instruction and evaluation, but that has increased student satisfaction and reduced student appeals.

Grading and Evaluation Guides

The first step in ensuring consistency was to determine a marking and evaluation scheme. While this might appear counter-intuitive, one of the most common complaints about the course was the lack of understanding about how expectations were communicated and how work was evaluated. As grades are, in the common-core year, of utmost importance, as they determine acceptance into second-year programs, most students are fairly grade-focused.

The student frustration with the expectations and evaluations was clearly reflected in the USRI or student feedback scores. The University uses a seven point scale, where 1 is poor, and 7 is excellent, for evaluation. The key questions influencing the redevelopment were two: Content and expectations well organized and Evaluation methods clear.

In the 2007/2008 academic year, the course had its lowest scores in these two areas: 3.34 in organization, and 3.02 in evaluation methods. As both of these were well below the school average (4.14 and 4.46 respectively), this was clearly an area where the course needed significant improvement.

In order to improve the evaluation, the instructor team began by examining several formats. The course had previously graded numerically, with a set of criteria for each grade level, which were never revealed to the students. Although this method allowed for a high level of detail, it was not applied consistently, and could be very confusing for coaches. A survey of coaches, conducted by distributing three papers to each coach and asking for their evaluations, revealed a significant discrepancy (~11%) between the highest and lowest coach grades. This method was discarded.

After deciding a new format was necessary, the team turned to the academic literature [7-12]. A basic survey indicated the overwhelming switch to rubrics, but a formal rubric was considered and discarded. The great benefit of rubrics is their specificity, not something that is an asset in a course that looks for inventiveness and open-ended solutions [8,11-14].

Nevertheless, the rubric format is both familiar to students from their secondary education and offers a clear, legible layout that decreases confusion. Thus, a modified rubric was decided on. Starting with a format originally developed by the School of Liberal Arts at H____ C____ ITAL for their Communications courses[24], the team developed a physical template that would lay out the requirements for each element, and then had a grid so that each element could be graded on an alphabetic scale. The same basic format was retained for assignments that are graded numerically, ensuring visual consistency, and decreasing the confusion about how grades were assigned (see Appendix 1, 2, 3 for grading guide examples).

Once a grading format was developed, an assignment format had to be created. Working with a format suggested by D. O__, an electrical engineering instructor for the course, a multi-document format was created. Previous iterations of the course created assignments for each 'deliverable'; each document or presentation that would be evaluated. Professor O___ noted that during his time as a coach, this format left students focusing on each individual deliverable but overlooking the project as a whole. Professor O___'s solution was a document that gave a project overview, and then individual documents for each deliverable.

Several formats for the overview were considered, with various level of detail. One important element that all team members agreed upon was the necessity of an introduction that linked the project to 'real world' work, giving students an understanding of the usefulness of the projects. In addition, a clear outline of the project expectations, stages for the project and brief descriptions of each deliverable, as well as due dates and grade weights were included. All project overviews are organized in an identical order, so that students can find the important information (dates and grades) easily (see Appendix 4, 5 for challenge overview examples).

Individual deliverable documents are created for each assignment, after project discussion. In most cases, deliverables are a combination of oral presentations and reports. Typically a three week challenge would have one to two reports, usually an interim or status report and a final report; and some form of demonstration or final product testing. Longer challenges add oral presentations, separate drawing assignments and personal reflections or workshop notes in the student lab logbooks.

Process of Challenge Development

At the start of each semester, challenges for the following semester are divided up. In general, each of the full-time instructors (currently Dr. D. C___ and Prof. M. E___) develop one of the outreach or partnership challenges, with current instructors taking on the three other challenges. Typically the electrical or computer engineering instructor takes on the LEGO MindStorms challenge, as that challenge is guaranteed to involve programming, and the Rube Goldberg Challenge is typically assigned to the newest instructor, as it requires the least development.

Depending on the challenge, planning time can range from a few weeks to a year. The current Partnership Challenge involves a partnership with a local homeless shelter and education program; the planning for the challenge started in January 2009, with a challenge launch date of February 24, 2010. Other challenges, such as Rube Goldberg, can be executed in as little as three weeks, with the majority of the time being spent on refining the restrictions on the build.

Challenge Partners

In the two large-scale challenges (the Social Awareness Challenge and the Partnership Challenge), the instructional team looks for partners in either industry or the non-profit sector that will offer additional depth to the challenge. In many cases, the team has approached, or been approached by, a non-profit group who were looking for potential solutions to outstanding issues. In some cases, the team approaches a group to see if they have a challenge that the course may be able to present potential solutions to. In either case, the potential partnership is carefully explored[6,7].

In general, a partnership starts with a series of meetings, where the partner is introduced to the course's lab space and given examples of the kinds of solutions the course can generate. It is essential that partners understand that as a first-year course, the students cannot present final solutions, and that they will usually produce reasonable proofs-of-concepts, but not direct-to-market solutions. In addition, the team determines if the challenge is a reasonable fit for the course; challenges that are highly specific are usually not useful for our students[20, 21, 22].

Planning

For each challenge, the instructor in charge lays out an overall outline, including potential due dates and overviews of the different deliverables. This outline is delivered to the communications instructor, who generates an initial challenge overview and deliverables documents.

The communications instructor then distributes copies of all documents to the team at least 3 days before the weekly team meeting. Each team member brings their edits to the meeting, and a new set of documents is generated. Originally each team member sent their edits back to the communications instructor, but the shear number of edits, re-edits and commentary over email became overwhelming. A single face-to-face meeting has resolved this solution, although the meetings can still be fairly contentious.

Once a working copy of the document has been created, the communications instructor reviews the document for compliance with all formatting and layout requirements, and sends it to the course co-ordinator and the challenge head for final approval. The documents are then PDF'd and posted to Blackboard (see Appendix 6-9 for deliverables documents).

Grading Guides

Grading guides are developed parallel to the original challenge documents. In the initial challenge planning meeting, the weight of each deliverable is determined, along with the method of evaluation. The challenge head decides on relative weights for each section of each deliverable, with some elements being dictated by other instructors as necessary (formatting elements are determined by the communication instructor; visual arts elements are determined by the fine arts instructor).

Grading guides are posted at least one week before deliverable due dates, so that students have the opportunity to see the grading formula. For the most part, grading guides are simply re-organized versions of the deliverable documents; however they often give relative weights of sections, which allow students to prioritize their work (see Appendix 1-3).

Grading of Written Work

Once written deliverables have been handed in, it is necessary to evaluate them. While all written papers are done in groups, and thus each lab room has only 6-8 papers per assignment, there are still over 200 papers handed in for each assignment. This is the single greatest challenge to course consistency, as it is for many large courses. With 24 coaches, ensuring that the grading guides are applied consistently is difficult. Previous studies done with coaches showed a large divergence in grades. In order to encourage consistency, a series of grading exemplars are posted for coaches. For each assignment, 20-26 papers (four lab rooms worth) are collected. The communications instructor marks the set, in consultation with the instructor in charge of the challenge, and they select at least one 'A', 'B' and either 'C' and 'D' or 'Redo' exemplars. These papers are anonomyzed, annotated and posted for all T.A.s as examples of the work standard for the paper. While this is very time consuming, it does ensure consistency to a much greater degree than previously demonstrated in the course.

In the first year of the new evaluation format, a sample set of papers were evaluated by coaches using the exemplars, and then compared, on four separate occasions. The first group of papers, (the second report of the first semester) showed a discrepancy of ~2 letter grades (A – B+, for instance). While a direct comparision to the numeric system is impossible, using the departmental average of 15% for the B- - B+ and A- - A+ scale, the two letter grade discrepancy would indicate a numeric discrepancy of 6% - 9%, a drop of almost between 20% and 38%. By the third group of papers, (the second report of the second semester), only 5 of the 24 coaches showed graded outside of the generally agreed on letter grade, and all 5 were a single letter grade below. This represents a dramatic increase in consistency, one that justified the change in evaluation format.

It must be noted that a letter grade grading system does have more room for flexibility, given that the letter grades represent a 3-5% grade range. It is unlikely that coaches, asked to arrive at a numerical grade, would arrive at grades closer than the 3-5% range. However, since grading written reports is inherently subjective, a grade range of 3-4% would be highly likely regardless of evaluation method.

Other Grading Methods

Oral presentations, which preclude exemplars, are marked in one of two ways. In both cases, a grading guide is developed and distributed the same way the written work guides are. In short, in-class presentations, the marking is conducted by the coaches, with the Lab Instructor observing at least two presentations in each lab room. This ensures that grading is consistent across the lab rooms, as the Lab Instructor can step in to adjust grades based on what they have observed.

For large-scale presentations, which include the end-of-challenge presentations for the two term-ending challenges, the marking is conducted by multiple instructors and T.A.s. At the moment, the marking team is composed of one Lab Instructor who is not the instructor for the group being evaluated, the Communications Instructor and two T.A.s, with the grades being averaged by the formula (Instructor grade x .34) + (Comms Instructor grade x .34) + (T.A. One grade x .16) + (T.A. Two grade x .16) = Final Grade.

Conclusion

While the system detailed here is complicated, and relies heavily on team co-operation, and access to an instructor familiar with academic writing, the feedback from students has been exceptional. After the first semester of the process (Fall 2008) USRI scores for Content and Expectations increased to 4.97 and Evaluation methods increased to 4.61. At the end of Winter 2009, C&E scored 5.28 and EM scored 5.15. While the Fall 2009 scores have not been released, we anticipate holding these scores. Perhaps more importantly, grade appeals to instructors dropped 50% in the 2008/2009 academic year (from 150 to 74), and in the Fall 2009 semester, only 68 appeals were reported. Along with the increased consistency shown by the coaches, these numbers would seem to indicate that the process, while labour-intensive, ensures that the student learning experience is far more consistent, focusing student attention on the content, not on grade complaints.

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APPENDIX 1:

ENGG 251: MATERIALS AND CONSTRUCTION CHALLENGE

FINAL REPORT MARKING GUIDE

CRITERIA	WORK LEVEL		
FORMAT (weight 1/8)	**REDO**	**B**	**A**
• Maximum 5-6 pages, not including cover page and appendices • Typed, single-spaced, 12 pt font • 1 inch margins • Page numbers, bottom center • Cover page: must include the project title; the names of all group members but NO ID NUMBERS; the group's Colour, Lab room and Table number; the due date; and the Coach name • Clear headings for each section			
PROJECT CONTENT (weight ½)			
Familiarization • Description of all items presented by the team, including images • Justification for selecting the chosen item. **Functionality** • The function of each major part or element, as determined by testing • The justification for each determination of function • Graphics and images as necessary **Testing** • The design of each test, including materials • The quantified results of each test • Graphics and images as necessary			
GRAPHICS FORMATTING (weight ¼)			
• Image/table/graph titles • Image labels • Tables/graphs labels			
LANGUAGE CLARITY (weight 1/8)			
• Clear writing • Consistent tense			
FINAL MARK			

Feedback Guidelines

- Each paper must receive some general written feedback. THIS IS NOT EDITING TO SHOW OR CORRECT ALL ERRORS
- Point students to the posted examples on the bulletin board. The intention of the posted examples is for the students to learn to correct their own mistakes, based on reflection. If the students are still not satisfied with the grade please send them to the instructors for further discussion.
- Be sure to comment on areas that were particularly well done, as well as offering suggestions on general areas of improvement.
- Please see the posted exemplars for examples of feedback comments.

APPENDIX 2:

ENGG 251: SOLAR DECATHALON CHALLENGE

RESEARCH REPORT MARKING GUIDE

CRITERIA	WORK LEVEL		
FORMAT (1/8)	**REDO**	**B**	**A**
• Maximum 3-4 pages, not including cover page, appendices, images/graphics and reference page • Typed, single-spaced, 12 pt font • 1 inch margins • Page numbers, bottom center • Cover page: must include the project title; the names of all group members but NO ID NUMBERS; the group's Colour, Lab room and Table number; the due date; and the Coach name • Clear headings for each section			
PROJECT CONTENT (1/2)			
Introduction to the Topic • Background on the topic • Any issues, problems or difficulties **Concepts** • 2-4 concepts from the final research areas the team is considering • The pros/cons of the concepts • The reason one concept was chosen/the other concepts were eliminated • At least one sketch per concept (integrated with the text)			
REFERENCES (1/8)			
• In-text citations for all quotes, paraphrases, data • Reference page at end • All references in IEEE format as laid out on attached document			
GRAPHICS FORMATTING (1/8)			
• Image titles • Image labels • One sketch per concept			
LANGUAGE CLARITY (1/8)			
• Clear writing • Consistent tense			
FINAL MARK			

APPENDIX 3:

ENGG 251: ENGINEERS WITHOUT BORDERS CHALLENGE

PROOF OF CONCEPT MARKING GUIDE

Lab Table: Team Members:
Coach:

CRITERIA	MARKS
PROOF OF CONCEPT	
• A unique application/modification of existing materials or design • Relevant to the community • Communicates the overall design functionality • A clear identification of the functional appropriateness of the design	**/30**
• Form and function have been integrated – has aesthetic value, shows attention to detail, looks professional and is visually appealing • Shows interesting/creative use of materials – i.e. sustainability(environmentally friendly) and accessibility (locally accessible/manufactured) has been considered in the proof of concept	**/20**
SUPPORTING DOUMENTATION	

• A poster
  o Must be suitable for a presentation
  o Show other aspects of the design
  o Justify the design process
  o Discuss the sustainable and environmentally friendly elements of the design
 	
• A research brochure
  o Contain background on the region chosen
  o Details the engineering research done for the project
  o Gives references
  o $8^{1/2}$″ x 11″ trifold format
	/35

OPEN HOUSE PRESENTATION	
• All members of the team are professionally attired • Team prepares a one-minute verbal overview of their Proof of Concept • All members of the team are prepared to answer questions and explain their design	**/15**
FINAL MARK	**/100**

APPENDIX 4:

ENGG 251: PREDATOR VS. PREY CHALLENGE

CHALLENGE OVERVIEW

THE DESIGN PROCESS

During the engineering design process, background research and analysis leads to the development of design requirements (i.e. what is the design supposed to do?). These requirements are used to create a design (i.e. how the requirements will be met). Note that several design alternatives are typically considered and evaluated. The most promising design approach is then selected, on the basis of engineering analysis.

The implementation of the design is the creation of an engineering prototype. To verify that the prototype meets the design requirements, testing is performed to validate the prototype against the requirements. A useful rule of thumb in engineering is that one should assume that a design does not work, unless it has been verified through testing.

The design process described above is not a linear one. As more understanding of the design problem is gained through the various steps of design, previous steps are revisited and design becomes an iterative process.

PROJECT CONCEPT

Robotics is a rapidly-developing area of engineering. Incorporating aspects of electrical and mechanical engineering, robotics design will be at the frontier of engineering for years to come.

In this challenge, each group will use the Lego Mindstorms NXT robotics kits as a rapid prototyping platform for a prey robot, one that will evade a predator robot in the test arena.

While all team members are expected to participate in the designing, building, and testing of the robot, clearly defined roles should be established at the start of the project to facilitate organization.

DESIGN REQUIREMENTS

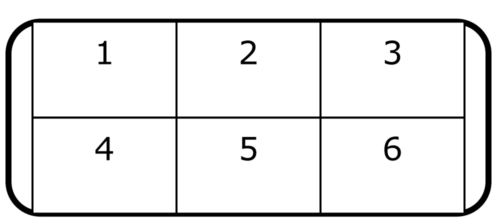
1. The prey robot must:
    - Avoid making any contact with the arena walls
    - Avoid the predator robot for 90 seconds (for full marks)

   The arena measures 1.93 m X 1.40 m X 0.25 m

2. Following the activation of the prey and predator robot, there will be no human intervention until the test is completed. Interventions include sound, light, touch, Bluetooth and wireless contact. Due to imperfections in the construction of the arena, either the predator or prey may be given a slight nudge, with the coach's consent (without penalty), e.g. if they get stuck in a groove or at the wall.

3. The lab coach will determine the order that the teams will be able to compete against the predator. For each trial, the teams will follow this order, one test per team at a time, until the lab coach calls an end to the competition at the end of the lab. Thus, teams will have multiple opportunities to test their prey against the predator. If a team is not ready to take their turn, then they will forfeit their turn to the next team and will have wait until their turn comes up again in the order. Teams are permitted to modify their robots between trials.

4. Each team must complete at least 3 trials against the predator. The best three trials will be averaged to determine the score. The arena will be divided into six sections, see figure below. The starting sections of the arena for the predator and prey will be determined randomly by the coach. The robots must be placed in the center of their section. The starting orientation of the prey within the section is up to the discretion of the team, the team will know the starting section of the predator before orienting the prey. The starting orientation of the predator within the section is up to the discretion of the coach. Both robots will not start in the same section.



5. The predator robot has a five second wait-time at the start of the program to give the prey a head start. This head start will not be counted in the total time.

6. The trial ends when any part of the prey robot containing the Brick makes contact with any part of the predator robot.

7. There will be a 5 second deduction for each prey contact with the walls of the arena. The duration of the contact does not affect the penalty. The number of times contact is made affects the penalty.

8. There will be a 5 second deduction for each piece of the prey robot that detaches during operation of the robot (pieces that detach due to contact with the predator do not result in a deduction). Each detached piece will be counted, e.g. if a block of Lego is detached, then all the pieces in that block will be counted. Detached pieces will not be removed or otherwise disturbed until the end of the trial.

9. The prey robot should be built to withstand a collision with the predator robot, such that it will be ready to compete in its next trial.

10. The prey robot may not permanently alter the arena or cause damage to the arena surface (no glue, liquid, fire, etc.)

Please note: the Lab Instructor will rule on any disputes according to the spirit of the competition

RESOURCES – MATERIALS AND EQUIPMENTS

1. Lego Mindstorms NXT kit
2. Assorted Lego pieces in drawers
3. Elastic bands
4. String

No external materials are permitted, and the parts may not be modified

<u>Absolutely no glue, tape or other adhesives may be used</u>

RESOURCES – DOCUMENTS (Located on Blackboard)

1. Quick Start Programming Lego NXT (start here)

2. NXT Tutorial (must read this for programming, after quick start)

3. NXC Programmer's Guide (for advanced programmers, beginners can skip this and stick with the tutorial)

DELIVERABLES

This challenge will be competed in stages, with each stage producing a deliverable, or element for evaluation, by a specific point in the challenge timeline. The complete specifications of the deliverables are in their own handouts, but the four deliverables are:

1. Status Report
   The status report is a short (3 pages) report detailing the work that has been done so far on the planning and construction of the prey robot, and laying out the work still to be done.

2. Test One
   This is the first opportunity for teams to test their prey robots against the predator robot. Each team must complete at least three tests against the predator, and will be graded on an average of the tests.

3. Test Two
   A week after the first test, each team will match their improved prey robot against the predator robot a second time. Again, each team must complete at least three tests and will be graded on an average of the tests. Note that the predator may also be improved and there is no guarantee that the predator's design will stay the same.

4. Final Report
   This is a summary and analysis of the completed challenge. Each team will discuss the design process, analyze the final design and discuss the computer code used.

GRADING BREAKDOWN

Deliverable	Due Date	Weight
Status Report	Start of the first lab of the week of September 21st, 2009	2.5%
Test One	Last 1.5 hours of lab, the week of September 21st, 2009	2.5%
Test Two	Last 1.5 hours, the week of September 28th, 2009	5%
Final Report	Start of the first lab of the week of October 5th, 2009	10%

APPENDIX 5:

ENGG253: RUBE GOLDBERG CHALLENGE

CHALLENGE OVERVIEW

INTRODUCTION

As engineering challenges in a variety of fields become more complex, engineers are increasingly working as part of a team that is itself part of a larger team. These layered projects, where each smaller team creates one or more elements of a greater whole, require expertise in project management, team dynamics and co-operative development, in addition to the increased engineering pressures of integrating a design with other elements. The Rube Goldberg Challenge is an introduction to collaborative design process.

RUBE GOLDBERG MACHINE

A Rube Goldberg Machine (RGM) is one that performs a simple task in an overly complicated, convoluted manner. The final task of this challenge's RGM will be to fill an egg carton with balls. Each lab will create a SINGLE RGM consisting of two parallel branches. The RGM will be designed and built as an entire lab challenge.

Each team's steps will begin with an input from the previous team and end by initiating the next team's set of steps; therefore specific attention must be paid to interface design. The machine will function as a whole and the performance grade will be based on the entire lab's machine.

A Project Management team will be responsible for facilitating the successful delivery of the RGM, using PM techniques such as: planning, scheduling, monitoring, and control.

Teams will be responsible for:

1. Researching the engineering theory behind each stage
2. Designing, building, and testing each step
3. Designing, building and testing the interfaces between steps and sections, and testing the overall performance of the machine, with technical justification
4. Consistent interfacing amongst adjoining teams.

DESIGN REQUIREMENTS

1. The RGM will start at one point and split into two parallel branches: primary and secondary.

2. Each team is responsible for a "section" that is comprised of at least four (4) steps: three (3) in the primary branch and one (1) in the secondary branch (Refer to the RG Schematic Diagram). Note this is only a minimum. Teams are free to exceed the number of steps. The exception to this is that The Project Management team will be responsible for the first 2 steps in the primary branch and the first step of the secondary branch.

3. The RGM will be constructed by connecting teams' sections in series to form one machine.

4. Each team must demonstrate a "touchless" interaction, within their section. Each team must come up with a unique touchless interaction that may not be repeated within the lab. Touchless interactions can involve (but are not limited to): magnetic or electromagnetic fields, light, sound, heat, wind, etc. The PM team does not have to perform a touchless interaction.

5. The parallel branches must combine and both contribute to completing the final task.

6. The final task of the RGM will be to place at least one ball in each compartment of a 12-egg, egg carton. Marks will be deducted for each compartment that remains empty or for each ball that misses the egg carton. The type of ball shall be chosen by the lab. No ball shall be closer than 30cm to the egg carton when the RGM is initiated. In the final position, the balls will be in direct contact with the egg carton (e.g. you cannot simply lower one egg carton full of balls into another egg carton); and the balls will be loose (i.e. the balls cannot be fixed to anything, for instance, glued or screwed to an assembly).

7. The RGM must complete its operation in 2 minutes. Marks will be deducted for times over or under this time.

8. The RGM cannot use fire or uncontained liquids in its operation.

9. The entire RGM must fit in the area defined by the footprint of ONE of the tables available in the labs. It may sit on the floor, or on any support provided by the table, but it may not extend past the footprint of the tabletop. The maximum height of the RGM is two (2) meters from the base to the top. The Rube Goldberg Machine must be easily transportable from the labs to the 2^{nd} floor foyer (i.e. through the lab doors), where the demonstration will be held.

10. The only human intervention allowed is the impetus to begin the first step in the machine. Marks will be deducted for each additional human intervention. All Mindstorms or other devices must be turned on and started before the impetus is given. The timing between the start of these devices and the impetus must be unrelated.

11. The RGM must demonstrate robust design by running at least 3 times within the formal demonstration.

Note: There will be a performance score given for meeting these criteria. The criteria by which the performance will be judged can be found in the Demonstration document.

Project Rollout Activities

1. The entire lab will select a theme for the overall Rube Goldberg machine.
2. A project management team will be selected by the lab. Students can volunteer to be members of the project management team. If there are more than 4 volunteers, then the lab will conduct a lottery amongst the candidates.
3. An anchor team will be selected by the lab to complete the final and most challenging step, using the selection process above.
4. The lab will assign the order in which the sections will proceed and negotiate the interfaces between sections.

AVAILABLE RESOURCES

- All lab tools
- All general Lego
- All lab computers
- Any found materials

- Any other materials required (not to exceed $20.00 per table)
- One Mindstorms kit per lab table

Note: You may NOT use tape, glue or any adhesives on the Lego blocks or Mindstorms Brick.

DELIVERABLES

No.	Deliverable	Weight	Due Date
1	Team Contract	2%	First lab, week of Jan. 25, 2010
2	Interim Report	5%	First lab, week of Feb. 1, 2010
3	Demonstration	8%	Long lab, week of Feb. 8, 2010
4	Final Report	5%	First lab, week of Feb. 22, 2010

APPENDIX 6:

ENGG251: SOLAR DECATHLON CHALLENGE

ORAL PRESENTATION

PURPOSE

Public presentations are an essential skill for all engineers. When many smaller teams work together on a larger project, often each team will familiarize the other teams on one area of research to cut down on preparation. In these cases, a team will often be called on to present as a group with each engineer being required to not only present their own research but also integrate their specific area into the greater presentation without overwhelming it.

The assignment is designed to give students a chance to present their sustainable energy research to their lab section. **Every member of the team will need to participate in the presentation**, but the presentation will need to be a single, seamless whole, not a series of individual mini-presentations.

CRITERIA

The group must plan the presentation in advance and be within the time limit of five to eight (5-8) minutes. Presentations will be cut off when the time limit is exceeded.

The presentation is PASS/FAIL, but five (5) areas will be considered:

Structure

- Introduction of each team member
- Clear transition between parts
- Each team member takes part in the presentation

Content

- Overview of the aspect chosen (1 of 8 on sustainable energy aspects list)
- An emphasis on the points listed on the powerpoint list
- Clear summary of information

Non-verbal communication

- Eye contact
- Not reading from notes
- Professional appearance
- No squirming, fidgeting, jingling change, etc.

Verbal communication

- Technical vocabulary appropriate for a knowledgeable audience

- Adequate volume
- No sub-vocalizations (ums, ers, likes, etc)

Visual Aids

- No PowerPoint
- Use Document Camera to show visuals
- Visuals are clear and easy to see from a distance
- Explain visual information

APPENDIX 7:

ENGG 251: ENGINEERS WITHOUT BORDERS CHALLENGE

PROOF OF CONCEPT DEMONSTRATION

PURPOSE

The proof of concept demonstration is an essential skill for any design engineer. While it will sometimes take the form of a classic oral presentation, more often the engineer or engineering team will have to demonstrate the work in a forum situation where many teams are presenting at once, and they do not necessarily have the audience's undivided attention. In these cases, the audience will come to the presenters, and the presenters must be able to hold that audience's attention.

The proof of concept demonstration will be conducted in an 'open-house' environment. Each lab team will have their proof of concept prototype, as well as supporting documentation to explain and elaborate on their demonstration. The audience, including professors and visitors to the class, will move around the room and visit each group, who will in turn "pitch" their ideas.

CRITERIA

While the open house is the venue for the demonstration, the Proof of Concept and the presentation documents will make up the majority of the grade, rather than the presentation itself.

Proof of Concept:

If you have developed a device or object; or extensively modified a device or object: Proof of Concept Prototype

- A prototype (3D) of ONE ASPECT of the team design.
- Must show an important/relevant aspect of the team design
- Be portable and built to scale
- Show interesting use of materials
- Must fit on lab table, and fit through lab doors

OR

If you have developed a system, extensively modified a system or created a device or object that cannot be physically modeled: A Proof of Concept Website

- Multiple pages documenting all aspects of the team design
- Images of all aspects of the design
- Maps, photos and other images to back up project justification

IN ADDITION, ALL GROUPS MUST COMPLETE THE FOLLOWING:

Supporting Documentation

- A poster
  - Must be suitable for a presentation
  - Show other aspects of the design
  - Justify the design process
  - Discuss the sustainable and environmentally friendly elements of the design

- A research brochure
  - Contain background on the region chosen
  - Details the engineering research done for the project
  - Gives references
  - $8^{1/2}$" x 11" trifold format

Open House

- Professional demeanor
- One minute overview
- All members of the team participate
- Each member of the team is able to answer questions

APPENDIX 8:

ENGG 251: PREDATOR VS. PREY CHALLENGE
FINAL REPORT

PURPOSE

Every development or design process has numerous requirements for engineering documentation. For this challenge, the report will sum up the entire challenge, from the initial development stages to the final product, and analyses the prey robot and the process used to design it.

Once a design project is finished, it is essential to review the entire process and consider what could be changed or improved the next time you work on a project. This is a common activity in industry and is referred to as "lessons learned."

CRITERIA

This report has several criteria:

Format

- Maximum 10 pages, plus appendix (computer code) and cover page
- Typed, single-spaced 12 pt font (Verdana or Georgia)
- 1 inch (2.5 cm) margins
- Cover page: must include the project title; the names of all team members but NO ID NUMBERS; the team's Colour, Lab room and table number; the due date; and the coach's name
- Headings for each section

Design Process

- Briefly describe all alternative design approaches that were considered for the robot design. Justify the choice for the selected design approach for your prey robot.
- Describe what changes to the robot were made after round one testing, with justification.
- Provide a detailed description of the prey robot, including its structure (pictures will be very useful), functionality (how it works, including: sensors, motors, algorithms), and explanation of the software.

Performance Analysis

- State the performance of the robot during the tests.

- Describe improvements that could be made to the robot to improve its performance.

Code Analysis

- A detailed analysis of the computer code, including possible changes

Lessons Learned

- Reflect on the project and describe what worked well and what didn’t, in terms of the design process, team dynamics, etc. Provide advice for future projects, gained from experience on this one.

Images

- Labelled images of all aspects of the robot

Appendix

The code MUST be in COURIER FONT. Note that in software development, special fonts, such as Courier, are used because they have a constant width for characters and spaces, so that formatting is easy to achieve (so code lines up).

- The full code for controlling the robot

APPENDIX 9:

ENGG 253: THE MUSTARD SEED CHALLENGE

FUNCTIONAL REQUIREMENTS AND DESIGN PROPOSAL REPORT

PURPOSE

Functional requirements

The purpose of a functionality analysis is to determine *what* a solution needs to do. A common pitfall when presented with a problem is to immediately jump to one idea of what the solution might look like, or *how* it might satisfy the problem, but this will quickly and drastically narrow your creative design space. Proper functionality analyses keep the field of ideas wide open. A number of brilliant solutions come about when the creative problem solver moves beyond the problem as stated and more thoroughly considers what the solution really needs to do. In short, at this stage the designer must ask him/herself *what* to do and not yet *how* to do it.

For the functional requirements component of this report, you will be required to do the following:

- Define your overall project goal
- Interpret the needs of the key players to develop a set of functional engineering requirements
- Integrate your development into the overall theme of your lab

Design Proposal

The design proposal should give the reader confidence that the proposed design is realistic and achievable. There should enough detail to support the proposed design approach. For this component, you will be required to propose and justify the overall concept of your design.

CRITERIA

Each team will submit a single report, which will be evaluated in the following areas:

Format

Typed, single-spaced, 12 pt font (Verdana or Georgia)

- 1 inch margins
- Page Numbers
- Cover page: must include the project title; the names of all group members but NO ID NUMBERS; the group's Colour, Lab room and Table number; the due date; and the Coach name
- Headings for each section
- Table of Contents

Project Component Goals

- Briefly describe the primary content/skill set/target end-user etc. for which your development is aimed
- Restate your project goal

Functional Engineering Requirements

- Interpret the needs of the key players that you identified in your familiarization presentation into a set of conceptual engineering requirements
    - Requirements must be both measurable and testable. Remember, in your Testing Report, you will be required to develop systems to validate these requirements.
    - Use verbs to describe the functional requirements in terms of ***what*** the development should do.
    - As a simple example, suppose you are working as an aeronautical engineer and your client states the following need: "the part needs to be lightweight". After further investigation (meetings with client, etc.), you develop a testable, measurable requirement: "the product must weigh less than 100N (on earth)".
- In your familiarization presentation, you developed communications strategies for involving key players outside the team
    - Show how you used these strategies to define/refine your requirements. If necessary, refer to meeting minutes, e-mail threads, etc. in an appendix.
- Identify any conflicting needs between the key players
    - Ex. the client's ability to pay may conflict with the quality of product provided to the end-user

Design Proposal

- Propose and justify your design implementation

    - Provide an overview of the implementation of your project concept (e.g. will you develop a video game or a hands-on device)
    - Include sufficient detail about the main features
- Provide logical reasoning and justification for your design choices
- Create a visual representation (e.g. table or matrix) that traces how your proposed concept satisfies the client/end-user needs you identified

Integration

- Explain how your development integrates within the overall concept (theme) of your lab
    - Describe any necessary interfaces with other teams in your lab (e.g. software or physical connections), if required