Introduction

The Alan Blizzard Award was created by the Society for Teaching and Learning in Higher Education (STLHE) to honor its former President (1987-1995) Alan Blizzard, on his retirement, for his significant contributions to the Society. Designed to stimulate and reward collaborative efforts to enhance the effectiveness of university teaching and learning, the Award encourages and disseminates scholarship and effectiveness in teaching and learning. Each year the Blizzard Award winners present the Blizzard Plenary address at the Society's annual conference. A monograph describing the project is circulated to all Canadian universities.

The concept for the Blizzard Award was developed by a committee including Chris Knapper (President 1982-1987), Alan Blizzard (President 1987-1995), Pat Rogers (President 1995-2000) and Dale Roy (Coordinator, 3M teaching Fellowship Programme). The Alan Blizzard Award is sponsored by McGraw-Hill Ryerson (Higher Education Division) and *University Affairs*, Canada's higher education magazine. The Society is particularly grateful to Marlene Luscombe and Joe Saundercook of McGraw-Hill Ryerson, for their advice in the conceptual stages of the design of the Award and for their ongoing support of this project. McGraw-Hill Ryerson supports this Award as part of their focus on student success and faculty support. For more information go to www.mcgrawhill.ca/highereducation

This year, six applications were received from as many Canadian universities. This monograph summarizes the winning project form the University of Calgary. Readers who are intrigued by the possibility of adapting this project to their own institutions are encouraged to contact the authors directly. For more information and guidelines for submitting a nomination for the 2005 Blizzard Awards, visit the STLHE website at www.mcmaster.ca/stlhe/index.html

Aline Germain-Rutherford, Director
The Centre for University Teaching
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Decembre 2004

Introduction

Le prix Alan Blizzard a été créé par la Société pour l'avancement de la pédagogie dans l'enseignement supérieur (SAPES) en hommage à Alan Blizzard, ancien président (1987-1995), à l'occasion de son départ à la retraite, afin de souligner sa remarquable contribution à la Société. Destiné à stimuler et à récompenser les efforts de collaboration consentis pour améliorer l'efficacité de l'enseignement et de l'apprentissage universitaire, le prix encourage les lauréats en leur accordant des bourses d'études. Chaque année, les lauréats de prix Blizzard présentent une allocution à la séance plénière de la conférence annuelle de la Société. Toutes les universités canadiennes reçoivent une monographie décrivant le projet.

Le concept du prix Blizzard a été développé par les membres d'un comité composé de Chris Knapper (président, 1982-1987), Alan Blizzard (président, 1987-1995), Pat Rogers (président, 1995-2000) et Dale Roy (coordonnateur, programme de bourse de recherche en enseignement de la compagnie 3M). Le prix Alan Blizzard est parrainé par McGrw-Hill Ryerson (division de l'enseignement supérieur) ainsi que par Affaires universitaires, le magazine de l'enseignement supérieur au Canada. La Société voue une reconnaissance particulière à Marlene Luscombe et Joe Saundercook de McGraw-Hill Ryerson pour leurs conseils aux différentes étapes de la conception du prix et pour leur appui constant tout au long du projet. McGraw-Hill Ryerson apporte sa contribution au prix Alan Blizzard dans le cadre de l'objectif qu'il s'est donné de favoriser le succès des étudiants et de soutenir les facultés universitaires. Le site www.mcgrawhill.ca/highereducation offre plus d'information à ce sujet.

Cette année, six candidatures de différentes universités canadiennes ont été reçues. La présente monographie résume le projet multidisciplinaire de l'université de Calgary , récipiendaire du prix. Les lecteurs intéressés à adapter ce projet dans leur propre établissement sont invités à communiquer directement avec les auteurs. Pour obtenir plus de renseignements et connaître les modalités de candidature pour les prix Blizzard 2005, il est possible de visiter le site SAPES à l'adresse http://www.mcmaster.ca/stlhe/bienvenue.htm

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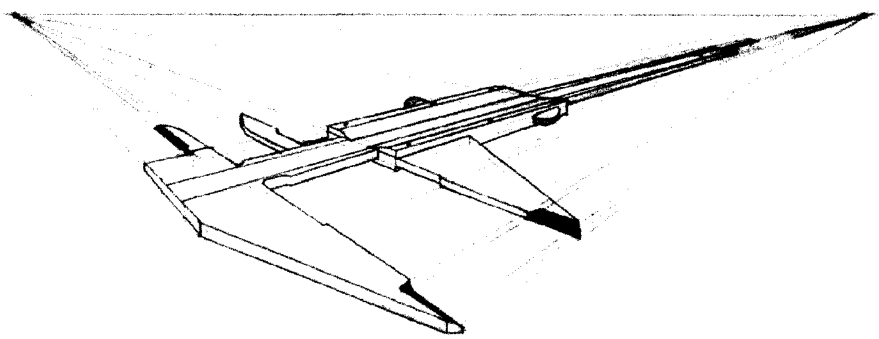
ENGG 251/253: FOSTERING CREATIVE PROBLEM SOLVING IN A MULTI-DISCIPLINARY ENVIRONMENT



UNIVERSITY OF CALGARY

JANUARY 2004

INSTITUTIONAL CONTEXT

The Boyer Commission's Report of 1998 called for a restructuring of undergraduate education at large research institutions. The report emphasized interdisciplinarity, undergraduate participation in research and the integration of communication skills into course work across the curriculum. At the University of Calgary the recommendations of the Boyer were taken up by the Undergraduate Curriculum Redesign Team. The team's final report, released in May 2003, called for a hands-on, inquiry-based approach to learning, particularly for first year students. The Canadian Engineering Accreditation Board (CEAB) stipulates that every student must have real world, team-oriented, open-ended design experience before graduation (CEAB, 2003).

Engineering 251/253 (ENGG 251/253), a collaboration of art, engineering and communication, is an interdisciplinary first year engineering design course first implemented in the 2002/2003 academic year in response to these challenges to innovate. The course is built around four pillars: drawing, design, communication and teamwork.

All 600 students entering the engineering faculty participate in the course for a full year. Student self-assessments of the 2002/2003 course indicate the course succeeded unequivocally in reaching the goals it was designed to accomplish (Fig. 6).

ENGG 251/253 at the University of Calgary allows all students entering the faculty of engineering the opportunity to *be* engineers. It presents students with real world, open-ended problems and requires that they access their own experience and intellectual resources to solve them. It is not a course *about* engineering but a course about *how to do* engineering. In a working lab environment we are able to challenge students to become independent, intrinsically motivated learners.

ENGG 251/253 meets the requirements of employers, incorporates inquiry-based learning into the student experience of engineering and retains and fosters creative students. While, historically, engineering graduates gained credibility through the management of technology, now technology is so sophisticated that credibility is founded on an engineer's ability to take initiative, to solve problems creatively and to communicate ideas both visually and verbally. As educators we are working to reclaim the creative nature of engineering.

GOALS

ENGG 251/253 has four main goals:

- Enriching the culture of engineering
- Supporting independence and interdependence
- Linking student experience with real world experience
- Integrating interdisciplinary learning into undergraduate education.

Course designers faced the double challenge of introducing engineering design to entry level students and of developing a course for 600 students. We use technology, four linked design labs and Blackboard, an interactive online source of course information, to engage students in the principles of analysis and design common to each of our disciplines. Our goal is to graduate students who are innovative members of the professional engineering community. We hope by engaging our students in real world, hands-on, interactive inquiry, we will help them develop into confident, creative engineers who have a strong understanding of the process and progress of an interdisciplinary approach to design.

One of the primary goals of ENGG 251/253 is to encourage students to take responsibility for their own learning. In contrast to traditional 'talk and chalk' methodology, the course requires that students move from passive receivers of information to active participants in their own education. We present students with real problems and ask them to use their own skills and ingenuity to solve them, reversing their expectations of the role of student and teacher. By engaging students in active inquiry, we encourage them to assume responsibility for their own learning processes.

By setting up a learning context in which students must integrate other aspects of their engineering course-work into their design solutions, we encourage them to act as creative, flexible, critically thinking and communicative engineers. By providing students with real world design work from real world clients, we engage them in true engineering design work where there is no right or wrong answer. In developing their ability to handle vague and ill-defined problems, students will become confident in their own definitions and decisions.

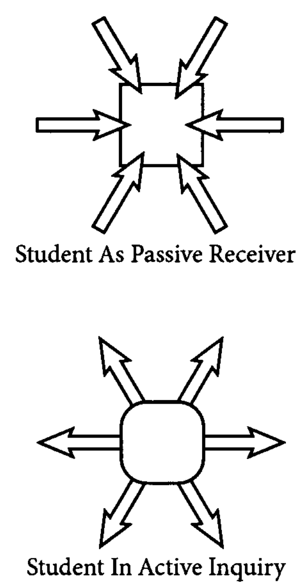


Figure 1: Students as active participants in an inquiry process

"Design is an activity of the mind and imagination. Engineering design includes the limitations imposed by the physical world. This course is providing the students with some exposure to that interface... it struck me that it was about time someone tried to teach this important aspect of the profession."

G. Gunthorpe (P Eng)
President
Delatee Enterprises Ltd.

A broader goal of the course is to establish a mutually beneficial relationship between academia and industry. What attracts industry to the design lab is the range of possible solutions generated by the students.

"We found the university can be a good source of raw talent for early development on some new product ideas... Over the years we have discovered that the real advantage of working with students on our projects lies in their unencumbered approach to early conceptualization. The theory being that student engineers tend to 'think outside the box' with less effort that seasoned engineers."

B. King (P Eng)
V.P., Operations
Head of Engineering
Tenet Medical Engineering

The specific learning outcomes of ENGG 251/253 reflect our major goals. Assignments in the design lab require students to work both independently and collaboratively. At the completion of the course, we expect students to

- work without direction
- work effectively in teams
- understand basic concepts of visual literacy
- employ the design principles of familiarization, functionality and testing
- demonstrate good communications skills, both oral and written
- solve problems effectively and creatively
- apply critical thinking and observation skills
- respect diverse talents and ways of learning.

PROJECT DESCRIPTION

ENGG 251 and ENGG 253, two consecutive courses, are a first year requirement for all first-year engineering students. This academic year students have worked, or will work, with these clients: Engineers Without Borders (EWB), Skate Canada, the Olympic Oval and Tenet Medical Engineering. Students work in teams of four over a course of several weeks on each project.

Their first project this year was to design environmentally and culturally sensitive solutions for water and housing in the small village in the Nilgiris region of India, a third world development project through EWB. The four criteria for these designs were

- Sustainable development
- Appropriate technology
- Environmental integrity
- Socio-cultural considerations.

By bringing a social context and conscience to their design experience, ENGG 251/253 places these engineers-to-be within the global community.

The second project of the first term was to design crash protection for amateur, outdoor long track community skating ovals across Canada. The students produced 150 crash protection designs, varying from the foam padding you might expect, to pliable fences of canvas panels on springs, vented air bags and innovative combinations of materials including hay bales enclosed by foam making the pads both inexpensive to construct and easy to store once the bales are removed (see Appendix G).

In the second term, students will first design skating robots to enter into the Skatebot competition in the Olympic Oval in March 2004. They will also work with a Calgary biomedical engineering firm to develop designs for a mechanism to hold limbs in place during surgery.

The range of design problems presented to students throughout the course requires the integration of the engineering knowledge presented in their other courses. Together these hands-on projects introduce them to the variety of employment possibilities in the field of engineering.

Instructional Team

ENGG 251/253 is implemented by a team of four instructors, sixteen coaches (teaching assistants) and one director of technology. An instructional team this size allows us to participate in extensive faculty-student contact, which has a significant impact on student satisfaction (Umbach and Porter, 2002).

We have one hour of lecture a week in which professors introduce key ideas and course concepts followed by two labs (one 3 hour, one 1½ hour). Students are guided in their inquiry by graduate student coaches (Fauvel *et al*, 2003; Brusse-Gendre *et al*, 2003). Each coach works with a lab of eight or nine four-person teams; four linked labs run concurrently so that coaches from each discipline are available to all teams at all times (one drawing coach, one communication coach, two engineering coaches). The course is designed and coordinated by four faculty members: two from the faculty of Engineering, one from the faculty of Communication and Culture, and one from the faculty of Fine Arts. Coaches and instructors meet weekly to prepare for the week's labs and to review issues from the previous week.

Design

ENGG 251/253 is structured around the design process, the link between each of the three disciplines. Principles of visual design, argument design and engineering design are close enough that they reflect and enhance one another. Strategies of divergent and convergent thinking, imbedded in the design process in each discipline, provide a rich context for learning (Paul, 2001).

The course, developed around the four pillars of design, communication, drawing and teamwork, is problem-based in its structure and inquiry-based in its emphasis on investigation, questioning and learning through experience.

Presented with large, ill-defined, real world problems, students are required to familiarize themselves with the problem and to narrow it down, to develop a range of design solutions, to develop tests to evaluate their solutions and to revise their design in response to test results. Instructors expect to see continuous design revision and justifica-

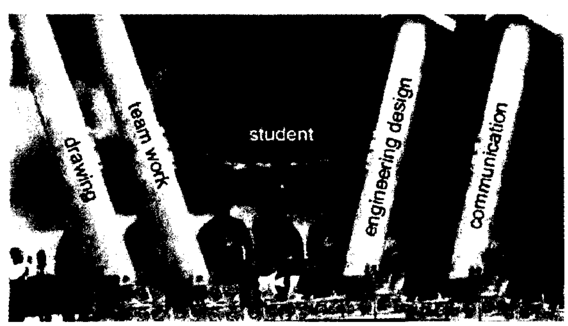


Figure 2: Student With Pillars.

tion through testing (Brusse-Gendre *et al*, 2003). Students must develop acute observation skills and hone their decision-making skills in order to succeed in the course.

The engineering design process is introduced to first year engineering students as the Design Trinity: familiarization, functionality and testing. Students begin by familiarizing themselves with the problem through observation and fact finding, determining the key functions the design must perform and developing preliminary design ideas. The process is iterative; as possible solutions are designed and tested, students see deeper into the problem and can define functionality more precisely.

The design trinity emphasizes design on two levels: the design of the solution or product and the design of the tests at each stage of the solution path. Continuous testing drives design modification. If test results do not meet established design criteria, those test results become the new base for strengthening the design. Students are encouraged to fail and to fail often in order to succeed faster.

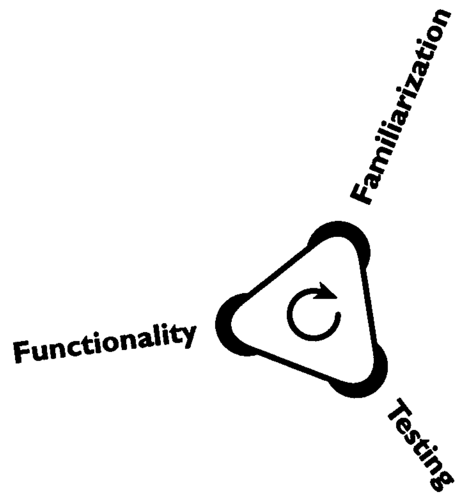


Figure 3: The Design Trinity

> *"In the coming term, I would most like to improve my use of the design trinity. Having now realized how helpful the design trinity can be, I hope to use it to our benefit more often. By familiarizing ourselves with the problem we can move to testing. Testing in turn leads to functionality. And functionality then brings you back to familiarization."*
>
> *Comment from student Performance Evaluations, Dec. 2003*

The design trinity imbeds critical thinking into the curriculum through its repetitive emphasis on idea generation and on analysis and testing.

Communication

All communication assignments in ENGG 251/253 are linked to the design projects (see Appendix E). Students keep engineering logbooks, write team contracts and prepare progress reports and oral presentations at milestone stages of their design. At the end of the term, they are asked to evaluate their own performance in the course in a performance evaluation memo to their coaches. The term projects involve students in the problems of their discipline which provides a necessary, rather than arbitrary, context for writing and oral presentation. Because students are actively engaged in their projects, they are motivated to write and organize their reports clearly in order to communicate their ideas effectively (Wlodowski, 1989).

Because students work collaboratively, and because they have many opportunities to revise and strengthen their work, they produce reports of very high quality. This is likely because they are not caught in the classic student dilemma of looking both ways (figure 4), one way toward the assigned (and imaginary) audience and one way toward the grade-giving instructor (Andre *et al*, 1994).

When students work on real world projects (figure 5), the student writer can focus clearly on the client as audience.

Impressed by the work of others, students' reporting improves steadily over the term. The initial reports of the first term focused on content and were poor in document design, but over the course of the term students began to adopt professional formatting conventions, to use correct engineering reference citation and to communicate their ideas visually through tables, sketches and drawings. The best proposals, the final assignment of the term, included concise executive summaries, clear organization of information, good presentation of data in charts and graphs, illustrative drawings and sketches and solid justification of each stage of the solution path (see Appendix F).

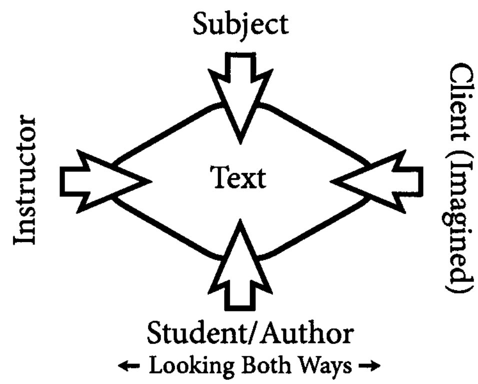


Figure 4: typical classroom writing situation

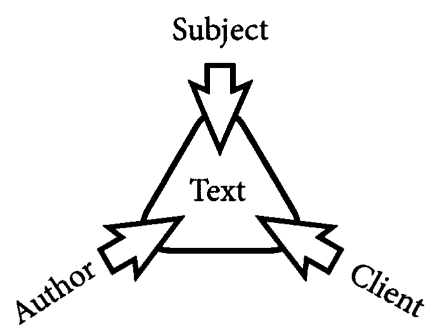


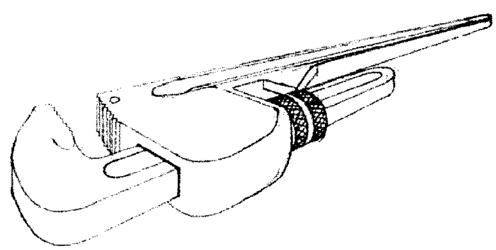
Figure 5: typical real world writing situation

Art

Drawing in ENGG 251/253 develops students' visual literacy through the fundamental principles of engineering drawing, isometric and orthographic projections. The art segment of the course stresses creativity in design and analysis as well as professional technical representation.

The six assigned drawings of the first term build student skill in visual representation. The instructor uses the document camera in the broadcast booth of the design lab to guide students through the basic construction of each type of drawing. Students draw along with the instructor, first as she draws on the document camera which is broadcast to all four labs and then again as she moves from lab to lab to repeat the drawing lesson. By the middle of the first term this method has the students confident in their abilities to produce basic engineering drawings (see Appendix I).

Because drawing is not only hand/eye coordination but also involves thinking in terms of proportion and design, students are encouraged to find weekly examples of good design and to paste photographs (or sketches) of these examples into their logbooks. By the end of the first term, students had developed strong perceptual and drawing abilities. The final drawing assignment was a challenge: an isometric projection of a hand tool that students had designed themselves, based on mechanical principles found in nature. The "biomimetic" assignment combined close perception, design imagination and the ability to visualize and sketch the resulting idea (see Appendix H).



Student 2-point perspective drawing

Student work was exhibited last year in juried exhibitions in the Mezzanine Gallery at the University Theatre and in the Art Department Gallery. This year student work will be shown in the gallery of the Faculty of Environmental Design and in a special exhibition in the Faculty of Fine Arts highlighting collaborations between fine arts and other disciplines.

Teamwork

Solving problems in the lab develops team working skills and team cohesion. One of the first term assignments is the team contract which we encourage students to revise as the term develops. Writing the contract forces students to consider how much they are willing to commit to the team, to define overall team goals, to think through issues of leadership and decision making and to foresee potential areas of conflict. We had many teams where one member chose to work toward a B in the course while the other three team members wanted an A. The team contract allowed team members to accommodate one another and to discuss levels of commitment and motivation without rancour.

We introduced the *Gregorc Style Delineator* to help students recognize their own learning styles and to work more effectively in teams. The delineator is a self-assessment instrument, which assists students in creating their own contexts for successful learning. The four main styles of the delineator indicate preferences in the way we learn, through theory or through hands-on experience, and the way we order information, randomly or sequentially. Once students identified themselves as Concrete Sequential, Abstract Sequential, Abstract Random or Concrete Random, they could see the ways in which their own styles aligned with their team members'. Using the delineator not only helped them understand their own learning preferences, it helped them work more effectively with their team members.

The *Gregorc* results provided an extremely effective icebreaker for instructors and coaches to discuss team performance with students.

> *"The Gregorc Style Inventory was very helpful. Thanks to this assignment we know the learning style of every member (of our team) and we were able to work more efficiently on our projects without problems."*
>
> *"During the term I learned the importance of collaboration to produce effective tests, designs and to complete and hand in work on time. With the help of others tests and designs can be worked and reworked in a shorter period of time and with more feedback. By participating in groups the stress associated with the assigned projects was eased with the sense of combined confidence and knowledge. ENGG 251 has proven the importance of collaboration and teamwork when solving problems."*
>
> *Comments from student Performance Evaluations, Dec. 2003*

Technology

The University of Calgary invested 1.28 million dollars as a start up contribution to the design and construction of four technologically advanced laboratories. The four linked labs circle around a central broadcast booth; instructors can broadcast to all labs simultaneously and can monitor lab activities through feedback screens. The four labs accommodate 150 students at one time. Each lab has a document camera, a projection screen, two computer terminals at each four-person lab table, and four complete tool boxes for each lab.

The design course began as a fourth-year option for 20 students (Caswell *et al*, 1999). Through technology we have been able to re-design the course for delivery to 600 (Caswell *et al*, 2003). While the educational foundation of design is not dependent on technology, delivery to large numbers of students is. Technology allows us to offer all students an interactive and responsive laboratory experience.

Our resources allow multi-media integrated androgogy and support the interdisciplinary nature of the course. Through technology, we have developed successful blended learning strategies. Course instructors produce instructional videos and often use media clips to introduce course content. We post all class assignments and readings on Blackboard and have adapted the site to include a gallery of student work, a design of the week section and a student driven discussion board. One of the challenges of working in real world contexts is that we often do not have control over scheduling. Blackboard allows us to disseminate important information to students as soon as we get it ourselves. It also presents us with a venue to celebrate student work.

The student discussion board offers students valuable peer support and provides a forum for them to solve their own problems and conflicts. Students commonly share information on assignments, pose questions and answers about course assignments and discuss course goals.

Course Grading

ENGG 251/253 reflects actual engineering practice: poor work does not get an 'F'; it gets revised and improved. Rather than receiving a letter grade on assignments, students receive a stamp indicating their level of achievement – excellent, acceptable, or *needs more work*. Student projects that receive the *needs more work* stamp must be redone until the work reaches a competent level. (Because students must revise until they receive an acceptable level of work, over 75% of first year students received their highest grade in this course.)

To ensure consistency of grading, instructors mark and carefully annotate student work and then review the marked samples with the coaches. Coaches receive grading guidelines and a package with samples of graded student work. Examples of excellent, satisfactory and *needs more work* are posted (anonymously) in display cabinets outside the labs so that all students can benefit from the instructors' close examination of the strengths and weakness of assignments. Students who receive *needs more work* have clear examples and detailed explanations of excellent work to help guide their revisions, a process which encourages continuous learning.

Two specific strengths of our assessment process are our team approach and our holistic methodology in marking assignments. Each assignment is reviewed by at least two members of the instructional team. Team members look for a broad understanding of the problem, a reasoned definition of the specific problems the team will address and a clear description, well supported with test results and design modifications, of the team's design path. Using competency-based criteria, projects are graded on the clarity of problem definition and the justification of the team's design decisions (Brusse-Gendre *et al*, 2001).

The continuous revision of work challenges students' concept of time. Projects that require sustained application throughout the term capitalize on good practices developed within the team (Kuh *et al*, 1997). By encouraging students to be self-directed and team-oriented, by allowing the re-drafting of assignments and by using online discussions in Blackboard, time is defined by the student, rather than by the instructor. Throughout the term, students become immersed in the experience of engineering design. Unlike other classes, where learning occurs in discrete time segments, learning extends beyond the lab in what we call incidental learning. Encouraged to bring all their experience to the design lab, students find they are never entirely removed from thinking about design. Incidental learning, the connections students make between their own work and the ideas and structures they see and hear around them, both on and off campus, enriches the student learning experience.

> *"I feel that this (incidental learning) is the best "thing" taught in ENGG 251. I now know how the different concepts from different subjects are put together to make certain items. For example, when the guest speaker came to talk about the pill counting machine, I did not know that something so simple was made with the help of so many physics concepts."*
>
> *"I have improved the most in incidental learning. The ability to realize when a random thought isn't so random can be quite useful. For instance, the idea to design wire cutters from crab pincers for our biomimetics project came to me as I thought about how good lobster tastes."*
>
> *Comments from student Performance Evaluations, Dec. 2003*

Unlike most post-secondary classes, ENGG 251/253 does not use a textbook. Instead the student's own work is the benchmark for teaching concepts and responses. The lack of a formal textbook allows flexibility within class so that instructors can respond to student questions and struggle (Caswell *et al*, 2001; Caswell and Schneider, 2001). A vital yet intangible element of the course, the notion of struggle recognizes that there is no progress without turmoil.

> *"To be completely honest I have to tell you that this course often frustrates me beyond belief. I found myself to be spending a humungous amount of time working on projects and assignments for this class that at the time I felt were utterly useless compared to the work I also needed to do in my other courses. Looking back I have come to realize that this course was very good for me, even the fact that it infuriated me at times. I am actually looking forward to next semester and going through it all again, which is something I thought I never would have said."*
>
> *Comments from student Performance Evaluations, Dec. 2003*

Continuous Course Development

The instructors of ENGG 251/253 are profoundly concerned with the improvement of the course through the processes of familiarization, functionality and testing both as they apply to the course itself and to its assessment. We have set up a coach discussion board on Blackboard so that we can document coach responses and suggestions after each week's labs. We also use bi-weekly CAT's (classroom assessment techniques) to collect feedback from the student teams and post regular question and answer sessions under a FAQ heading on Blackboard.

In understanding our students' experience, we can improve the quality of post-secondary education (Schönwetter *et al*, 2002, Kuh *et al*, 1997). We used the *Gregorc Style Delineator* not only to help students learn and work more effectively, but also to help us understand our own student body and to provide information for course development and curriculum redesign.

	Concrete Sequential	*Abstract Sequential*	*Abstract Random*	*Concrete Random*	*Hybrids*
ENGG 251	35%	23%	8%	23%	11%
Other students (3000)	40%	10%	20%	20%	10%
Differential for ENGG 251	- 5%	+13%	- 12%	+ 3%	+ 1%
ENGG 251 (Fac & Coach)	25%	5%	10%	45%	22%
Other instructors (300)	50%	10%	10%	20%	10%

Table 1: Gregorc results for students and instructors, ENGG 251 – 2003

When compared with a cross-section of other post-secondary students, we have a higher than typical concentration of Abstract Sequential students and a lower than typical population of Abstract Random students.

The high Sequential scores suggest that many of our students might, at least initially, be frustrated by the inquiry-based nature of the course. To counteract this early frustration, we have provided clear scheduling of assignments and due dates. Alternately, the high Concrete scores suggest that many students will be comfortable with the hands-on nature of the course design.

We acknowledged the higher than average number of Abstract Sequential students in lecture and suggested that these students, who look for authority and prefer to work alone, assume team roles such as research or defining overarching concepts and team goals. We encourage all students to get comfortable with their own styles and then experiment with stretching strategies designed to enhance their flexibility in working with others whose styles are either so similar or so different that the value of teamwork may be lost or compromised.

Having the delineator information has allowed instructors and coaches to work with students in developing and applying bridging strategies within their teams. Groups who achieve higher levels of academic and social integration dedicate greater effort to learning. The norm of such groups has been shown to be higher level of academic engagement (Ethington, 2000).

IMPACT ON STUDENT LEARNING

Course Assessment

The unique design of ENGG 251/253 requires a unique approach to assessment. Generally, the University of Calgary relies upon a tool known as the USRI (Universal Student Ratings of Instructors). This is a Likert scale questionnaire that asks students to evaluate their class experience including the course design, delivery and instructor. Originally designed to assess lecture style courses, the USRI does not ask students to reflect or comment on skills acquisition such as the development of problem-solving skills, or critical thinking – cornerstones of the ENGG 251/253 educational goals. Such reflection is critical, as students' perceptions of their courses strongly influence their perceived achievements (Ethington, 2000).

In light of this course's atypical design, an independent report was commissioned by the office of the Dean of Engineering to gather and assess feedback regarding the initial offering of ENGG 251/253, in the 2002/2003 academic year. This assessment report focused largely on capturing the nature of students' experience of the class, providing helpful feedback to course designers and recommending possible directions for future development.

The evaluation report outlined students' frustration with the open-endedness of the assignments, the drawing component and the grading method. In response, we introduced the new approach to drawing where the instructor now draws with the students using the document camera. Even students who say they 'suck at drawing' expressed much more confidence at the end of first term.

Although we have not changed either the grading system or the open-ended nature of the assignments, we have attempted to articulate our intent more clearly for students. In our minds, the most valuable aspects of the course are the open-ended nature of the assignments and the emphasis on continuous revision. Our goal is to graduate engineers with confidence in their own analytical and decision-making abilities.

Assessment of students' acquisition of specific skills lies at the heart of our stated goals and outcomes. When asked to agree or disagree with the statement that Engineering 253 (in winter 2003) had helped them develop skills in the following areas, student responses demonstrated unequivocally that ENGG 251/253 succeeded in accomplishing its goals:

1. Working collaboratively with others
2. Using drawing to communicate about design
3. Communicating about design through writing
4. Communicating about design through oral presentations

5. Using engineering skills to set design goals
6. Using engineering skills to assess design solutions
7. Working innovatively with design problems
8. Approaching learning tasks more independently

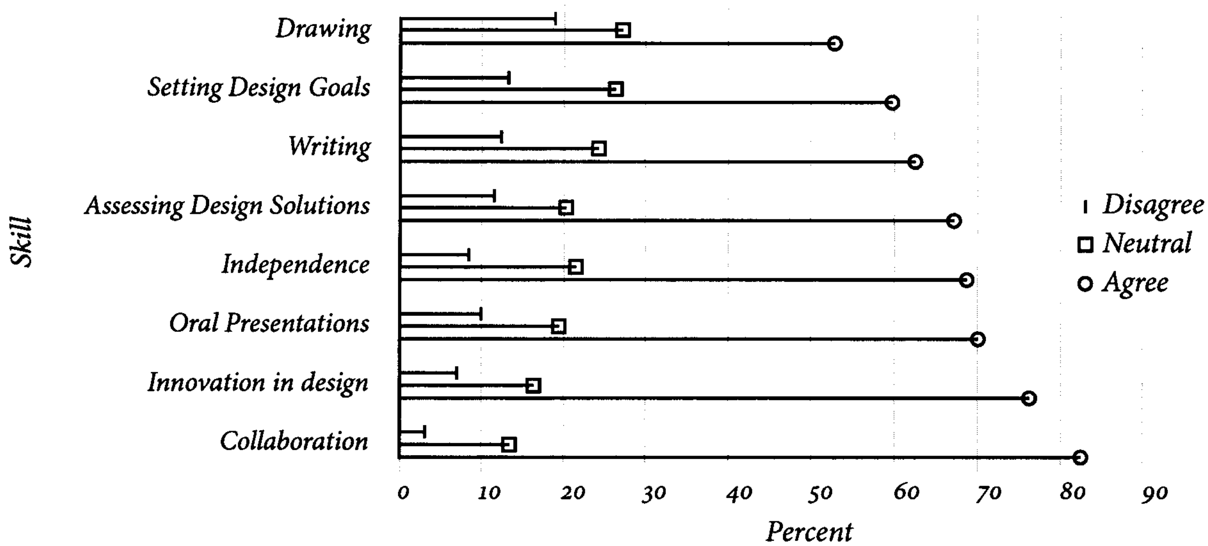


Figure 6: Respondents' self-assessment of skills development in ENGG 251/253 (Grossman, 2003)

A collaborative learning environment, such as ENGG 251/253, has been demonstrated to be significantly and positively associated with students' self-reported gains in problem-solving and group skills (Cabrera *et al*, 2001; Kuh *et al*, 1997).

A key word when discussing the broader impact of ENGG 251/253 is community. We have a role within both the educational and professional communities around us and it is in looking to those communities that much of our impact is made clear. ENGG 251/253 has received national and local media attention through the Learning Channel's coverage of last year's students' construction of speed skating crash pads at the University of Calgary Olympic Oval.

Several other educational institutions and faculties across Canada have contacted us regarding our innovative program: the University of Calgary Law School, Mount Royal College, the University of New Brunswick and Queens University.

DESIGN AS A MODEL FOR DEVELOPING INTERDISCIPLINARY COURSES

Many post-secondary institutions are calling for curriculum reform. Our experience shows that design provides a rich theoretical foundation on which to develop interdisciplinary courses. The similarities between engineering design and the patterns of inquiry imbedded in the writing process or in the making of art corroborate and enhance cross-disciplinary ideas.

The writing process, first codified by Aristotle in *The Rhetoric* (500 B.C.E.), lays out the basic stages of any design process: analysing the situation, defining a problem, generating a range of possible solutions, selecting the most appropriate solution given the situation. Writing, like engineering design, is an iterative process and requires continuous revision, reworking and refining to define and then meet intended goals. The various types of thinking imbedded in any design process are transferable across disciplines and provide a solid framework for an interdisciplinary approach to course development.

Design Process	*Types of Thinking*	*Design Stages*
Analyzing the Situation	Divergent Thinking	• Fact finding • Researching diverse views
Problem Definition	Convergent Thinking	• Analysis of problem to identify relevant issues/ criteria • Narrowing problem to key issues/ criteria
Generating Solutions	Divergent Thinking	• Idea generation (brainstorming, concept mapping)
Selecting Solution	Convergent Thinking	• Analysis, comparison & testing of designs/ solutions • Judging most appropriate solution
Revision	Divergent Thinking	• Revising design for intended purpose/ audience
Implementation	Convergent Thinking/ Strategic Thinking	• Planning the manufacture/ application of design/ solution

Figure 7: Design as a model for imbedding multi-logical thinking strategies (Douglas, unpublished manuscript)

Courses developed on a design model have the potential for meeting the Boyer Commission's call for an undergraduate curriculum incorporating undergraduate participation in research, the inclusion of graduate students as mentors and teachers and the integration of communication skills in course work across the curriculum.

FUTURE DEVELOPMENTS

Our partnerships with real world clients have resulted in extremely successful and well-received student projects. This year we worked with the local chapter of Engineers without Borders (EWB) on the project in India, described earlier. In 2005/2006, we plan to work with the Canadian National Office of EWB. Students will spend both terms working on third world engineering design projects.

In the fall of 2004, student teams will work with the Society of Automotive Engineering designing a crash protection system for the student Formula Design competition. In the winter term of 2005, students will work in their own community. The client is the City of Calgary, and teams will design a system to coordinate pedestrian, cycle and vehicle traffic in the downtown city core.

In support of our future projects, we are seeking funding for the installation of a machine shop, which would allow for more advanced prototyping and testing capabilities in the lab. We are also working on developing a design centre to facilitate industry/student contact.

We continue to work with other faculties across the University of Calgary campus in an effort to include an increasingly wide range of disciplines in the implementation of ENGG 251/253. We are talking with the faculties of Drama, Management and Social Sciences. In integrating these perspectives, we hope to develop broader perspectives for our students and increased opportunities for field experiences outside of the university.

Specific aspects of our future plans include offering institutional and community course development seminars as well as participating in industry professional development and re-training. Our association with industry will continue to include organizations such as Delatee Enterprises, Tenet Medical Engineering and Engineers Without Borders, as well as others in the wider professional community.

It is our goal to seek continued feedback from students, coaches, administration and industry and to further our research into new and effective evaluation schemes, culminating eventually in the development of a Design Stream as a degree minor for engineering students at the University of Calgary. We envision a Design Institute for off campus industry and enterprises to use as means of incubating projects using design principles.

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APPENDIX A

2004 Blizzard Award Application

UNIVERSITY OF CALGARY

Please note that we have included in your package a DVD copy of a seven minute documentary on our Engineering Design and Communication Course.

APPENDIX B: WHO DOES IT TAKE TO MAKE THIS COURSE RUN?

An Interdisciplinary Team Our 2003/ 2004 instructional team:

DARYL CASWELL is a professional Engineer, professional Musician and a Designer and Manufacturer of tools for the music industry. He has thirty years of experience as a teacher in engineering and music. Dr. Caswell uses his multi-disciplinary background in the field of acoustics, design and engineering education.

DIANE DOUGLAS is a writer and art historian. She taught ten years at the Alberta College of Art and Design before moving to the University of Calgary in 1991 to teach in Communications and Culture. She co-authored The Drawing Process (Prentice Hall, 1993) with U of C art professor Dirk van Wyk.

MARJAN EGGERMONT has a cross-disciplinary appointment at the University of Calgary in Engineering and Art. As an artist she has been in numerous art exhibitions nationally and internationally. Marjan has degrees in Military History (BA) and Fine Arts (BFA, MFA) and studied at The Royal College of Art (UK).

DIANE HOWARD started her career working as a television and radio News reporter and anchor. After working for CTV, CBC and Global both locally and nationally she obtained her doctorate in Communication Research at Florida State University. She has been teaching at U of C for eight years.

CLIFTON JOHNSTON has work as a professional engineer in the aerospace, oil & gas, municipal and biomedical industries. He has taught design at the University of Calgary for the past seven years, while continuing his research in biofluids, sports engineering and design methodology and teaching.

Course Designers ENGG 251/ 253 grew from the ideas of Dr. Caswell and Dr. Johnston and:

ROBERT DAY is Associate Dean, Planning, Faculty of Engineering and Professor of Civil Engineering. He was Team Leader of the Curriculum Redesign Initiative at the University of Calgary in 1999. He has led three major curriculum redesign initiatives and four major Canadian Engineering Accreditation reviews.

PETER DEACON is a practicing artist, a member of the Royal Canadian Academy of Arts and a full professor in the Department of Art at the University of Calgary. His interdisciplinary work involves Art, Engineering, Computer Science, Music, Architecture, Drama, and Environmental Design.

ROD FAUVEL has been a professor in Mechanical & Manufacturing Engineering at the University of Calgary since 1981. He has worked in construction, oil production, aviation and mining. His current research focuses on design methodology and engineering education. He continues to be an active designer.

COLIN MCDONALD is a manufacturing process engineer who has worked at Nortel Networks and for Repsol in the Libyan desert. Now at U of C, he is finishing a graduate degree in interdisciplinary engineering design combining mechanical and manufacturing engineering, fine arts, and environmental design.

Technical support

KENT PAULSON has been with U of C for seven years. For five years he collaborated with graduate students in Medical Research designing and implementing a wide variety of experiments. Given the chance to "build a better Engineer" he left Biomechanics to join the vibrant team of ENGG 251/253.

Coaches

In the 2003/2004 year our students were fortunate to have these interdisciplinary coaches:

ART	Erin Finley and Steven Mack
COMMUNICATION	Gaelle Eizlini and Andrea MacRae
ENGINEERING	Siu Ying Cheing, Bryan Donnelly, Helena Gerson, Jon Keech, Xiao Liu, Mohamed Nazir, Dan Palermo, Daniella Robu, Nico Sneeuw, Karthik Soundarajan and Renfeng Su

APPENDIX C: QUOTES FROM ENGG 251/253 STUDENTS

"I think this course is one of the most different courses that I've ever taken just because of how we're actually using some of the knowledge that we supposedly been learning all these years and how none of the stuff we're really doing is like a textbook question." (Student Performance Evaluations, December 2003)

"I think one of the things that make this course a lot different than any of the others is that all of our other courses are just laying the ground work and preparing us for real world applications. Whereas this one is actually real world applications." (Student Performance Evaluations, December 2003)

"What I like about this course is it's teaching us to be engineers ... as engineers we have to go out and actually design something new and this design course is kind of putting us out on the limb and making our brains tick [...] Design makes you think from a different section of your brain where you actually have to put your creativity at work with everything else you know and I think that's what engineering is so I think that's really beneficial." (Student Performance Evaluations, December 2003)

"I think what I've sort of learned about the course is that there is no right or wrong answers except, I guess they sort of mark you on how valid your reasoning is. Like 'why do you support this idea, why did you go with this idea?' So I really like that." (Student Performance Evaluations, December 2003)

"I noticed that as time went on in class, it became easier for me to concentrate on what work assignments were of higher priority than another. At first, it seemed frustrating to for me to accomplish all the work required in such a short time, but then I started getting used to it." (Grossman, Independent Assessment and Final Report, April 2003)

"Prior to the course, I did not know how to write many professional documents such as team contracts and proposals. The communication component of ENGG 251 taught us the vital skills of writing such professional documents." (Grossman, Independent Assessment and Final Report, April 2003)

"The projects or tasks we will face during engineering work may be huge and complicated and most of them can't be solved individually. Here, a team can be more efficient and helpful. Team assignments taught us how to generate ideas individually and then combine them to give us a much better one." (Grossman, Independent Assessment and Final Report, April 2003)

APPENDIX D: CLIENT LETTER EXCERPTS

"As a "client" for ENGG 251/253, I have enjoyed working with the students and they appear to have learned a great deal from their experiences with us. The "real-life" aspect of the design problems that are presented to them makes the experience as realistic as possible. I have also found their work to be invigorating. While some students will invariably not put much into the effort, the majority do a solid job and learn considerably from the effort. Then there are the top students that put out top-notch work that is of true value to us. Indeed, we have retained some of the students for legitimate follow-on research work, which expands both the value of their work and their educational experience. All in all, it's been fun and worthwhile for everyone involved and we here at the Oval look forward to continuing the collaboration."

January 2004
Dr. Sean Maw
Director of Engineering Research and Adjunct Assistant Professor
Faculty of Kinesiology
University of Calgary

"In the past we have looked to the more senior 4th year... Tenet Medical Engineering proposes to present a design problem to the first year engineers and ask them to generate conceptual solutions. In essence we hope to generate a brainstorming session with hundreds of minds to see if we can shake loose a usable solution. We look forward to the project and hold high hopes for its success."

January, 2004
Brent King
VP Operations
Head of Engineering
Tenet Medical Engineering

"Real life engineering projects typically involve somewhat ambiguous problems with many acceptable answers. Often the issue is to determine just what the real problem is. Nothing in the classical curriculum prepares the young engineers for this... Dr. Caswell and his team are attempting to provide these students with this unique learning opportunity."

January, 2004
Gary Gunthorpe (P.Eng.)
President
Delatee Enterprises Ltd.

APPENDIX E : COMMUNICATION ASSIGNMENTS LINKED TO THE CRASH PAD PROJECT

Engineering Project Reporting

Engineers typically submit reports at various milestones as their engineering project develops. They are also often asked to report their progress orally at project team meetings or with clients. Because of the technical nature of engineering, and the financial and legal consequences of your work, engineers are probably asked to present more ideas in writing (and orally) than most university graduates.

As a practicing engineer, your boss will not give you quizzes, problem sets or exams. You will be asked to convey your engineering ideas verbally (through reports and presentations) and visually (through sketches and drawings).

Communication Assignments Related to Crash Pad Design Project: Assignments

The assignments related to the crash pad project reflect common engineering practice:

- Individual Logbook (engineering records)
- Team contract
- Annotated bibliography (individual assignment)
- Progress Report: Familiarization
- Progress report: Testing
- Progress report: Design
- Proposal of Final Crash Pad design
- Team oral presentations on progress reports
- Performance Evaluation: Memo to your coach

Progress reports represent milestones in the development of your design. Write progress reports at these stages of your crash pad project:

1. After familiarization
2. After first round of testing in the oval
3. After design changes in response to test results

Certain sections of the progress reports will likely appear in your final report of the term, the proposal of your design to your client.

In addition to the written assignments, you will be called upon to report orally on your progress. Be prepared to present after each written assignment. Teams will be called to present randomly.

Please note that all of the assignments except the annotated bibliography are team assignments. Check each assignment separately for full requirements.

APPENDIX F

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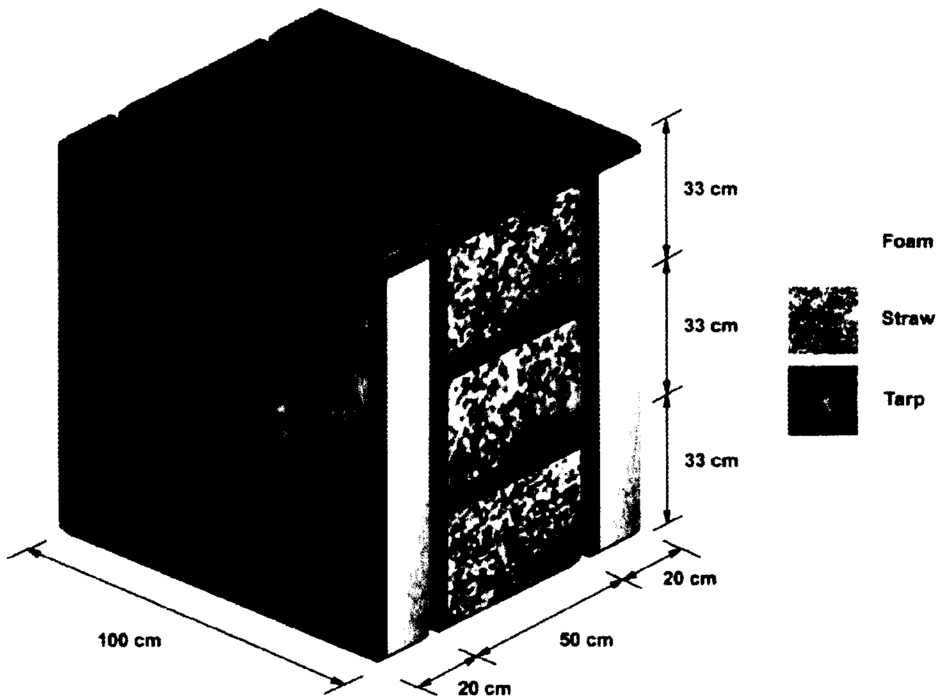
Note: Scanned from student report

APPENDIX G

Proposed Crash Padding Design

Based upon the background information presented above, several conceptual design ideas were generated. From these ideas, the design group decided to initially test the use of straw as a material for impact analysis. After subsequent testing and refinement, the proposed crash pad design shown in Figure 2 was devised.

Figure 2: Proposed Design of Crash Pad Unit



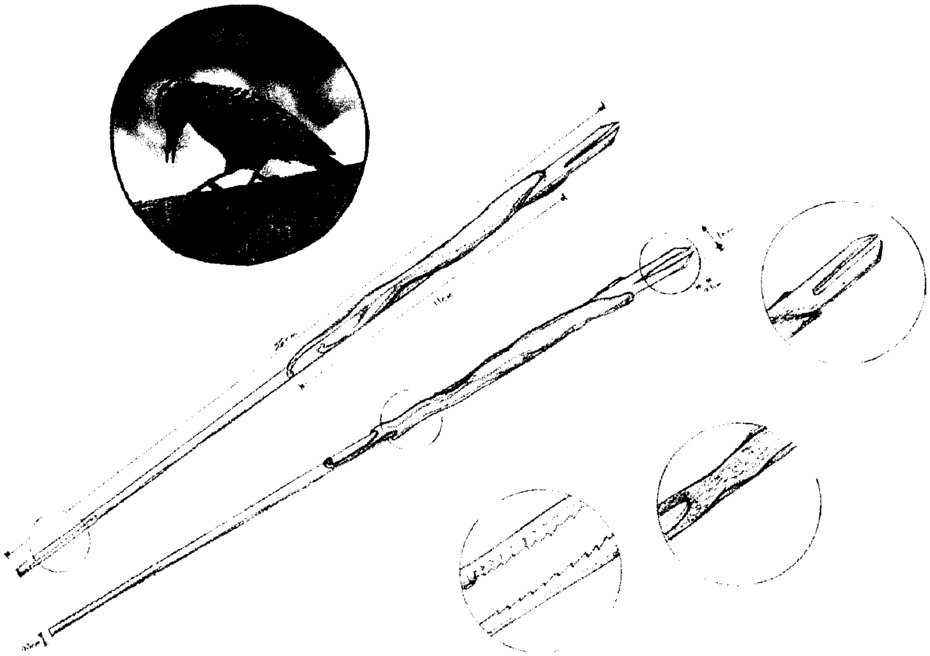
The proposed design unit consists of several modular components containing either straw or foam, each enclosed within a vinyl-coated polyester tarpaulin. As shown in Figure 2, the straw modules are height: 33cm, width: 100cm, depth: 50cm while the foam modules are height: 100cm, width: 100cm, depth: 20cm.

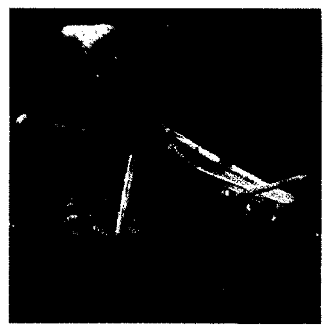
The basic arrangement uses an inner core composed of 3 straw modules stacked vertically and 2 foam modules – one on the collision side and another on the opposite side to sandwich the straw modules. This creates a basic, unified crash pad unit of approximately H: 100cm, W: 100cm, D: 90cm). Modules are secured to one another using Velcro. Straw modules also contain handle straps for easier moving.

Each crash pad unit is anchored and supported by either an existing snow bank or straw bales in the event that there is no available snow. Additional anchoring to prevent pads from shifting will be provided between adjacent crash pad units via interlocking straps or Velcro.

Note: Scanned from student report

APPENDIX H





Depending on the user, the chopsticks can sort, separate, and dig into the food

Using these chopsticks is simple. If you which to grab and separate an object from the dish. You apply a force on the grip of the chopsticks which will be equivalent to the force acting on the food because of the rough surface of the end of the chopstick. We used the claws of a praying mantis to obtain the rough surface our tool, because the claws of a praying mantis are shaped like a rigid blade; our chopsticks will be able to apply two forces, a normal force and a tangential force. This will apply a stress on to the food that will grasp onto it with less chances of slipping out.

To use the point of the chopsticks, this idea was taken from the beck of a woodpecker. An accurate tiny puncture will be applied to the food when force is applied in the same line of action as the point. The force must be greater than the food's critical resistance in order to puncture a hole in which the chopsticks hold on to. The chopstick takes advantage of the sharpness and preciseness of the beak, reducing the leakage of the juicy flavor of the food.

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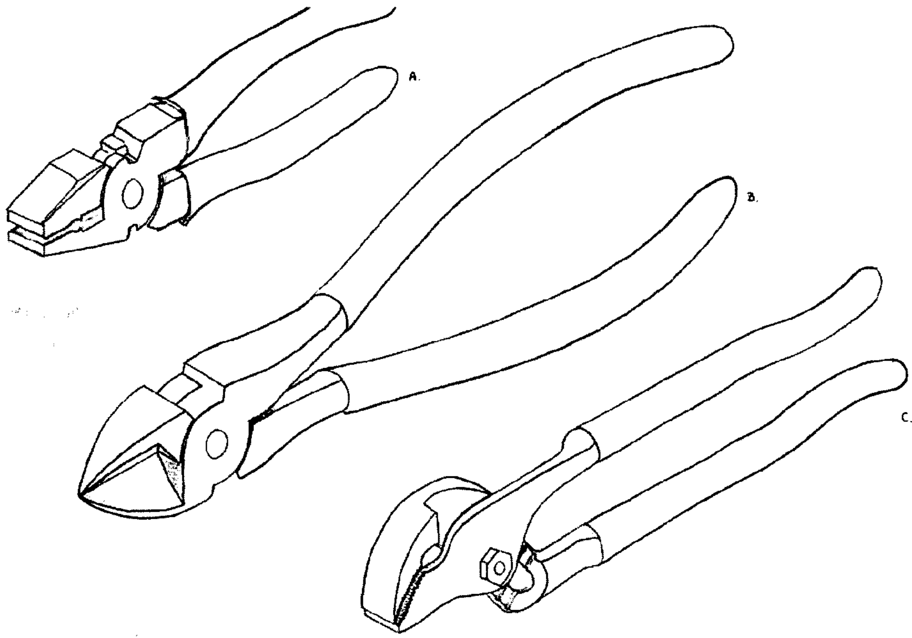
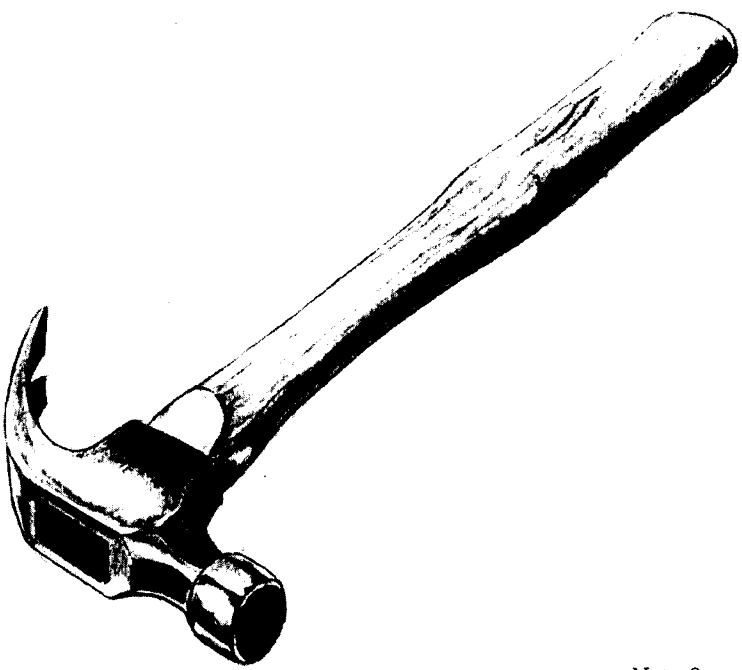
Note: Scanned from student drawings

APPENDIX I





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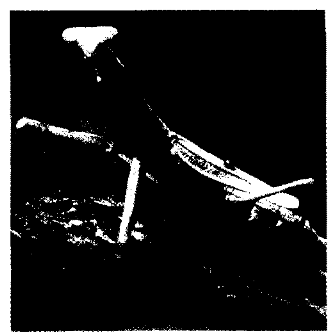

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