Team Development in a Preliminary Year Design Class

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ABSTRACT

This paper describes the approach taken to team development in a preliminary year engineering design class at the University of Manitoba. With this approach, student design teams assume a significant level of responsibility for the conduct of all components of the course. The course management system that emphasizes individual and collective responsibilities and formal training in team development is discussed.

Engineering Design is a required Preliminary Year course for all Engineering students at the University of Manitoba. More than 1200 students have taken this course since its introduction in January 1999. Classes as large as 100 students attend one lecture and one three-hour laboratory period per week. Laboratory work is Design Team based, so effective operation of the teams is critical if we are to meet our teaching goals.

Team membership is assigned by the professor. A maximum of 20 Design Teams are created per section, each with a target size of five students. Initially no Design Team will have fewer than four or more than six members. Team size can decrease during the term because of withdrawals, but in no case will a team continue with fewer that three members. Only twice since the initiation of the course has it been necessary to deal with the integration of depleted Design Teams.

The stated purpose of the course is to provide students with an introduction to the engineering design process. Design realities such as assumption, approximation, uncertainty, and compromise are introduced through open-ended, student-controlled, laboratory projects. Individual and collective responsibilities are emphasised through the course management system that has been developed.
During the initial offering of the course it was assumed that team development would occur as a result of the environment in which the students were required to operate. It was felt that specific problems could be addressed during the laboratory periods as they occurred. We quickly recognized that this was not a good assumption. Our typical first year Engineering students seem to bring a history of less than positive experiences in team projects. The team development skills we had thought to exist were, for the most part, not present.

In the fall of 2001, formal training in team development was introduced as a part of the course. This process uses the text, Team Developer\textsuperscript{1}, to support the formal training. The five design projects provide students with the opportunity to develop and practice the communication, decision making, collaboration and self-management skills necessary for individuals to be successful in a team environment.

Progress in the development of these skills is assessed through self and team evaluations that are carried out at mid and end of term. The format provided in Team Developer is used by individual team members to carry out a self-assessment and a team assessment in each of the skill areas. At midterm, students are encouraged to share their assessments with each of their teammates. In addition to providing the individual with insight into their own strengths and weaknesses, the exercise provides students with the opportunity to practice “giving” and “receiving” feedback. (See Appendix A, Part B and C)

End-of-term self and team assessments are submitted to the professor. In addition to the assessments, each team member is required to distribute “bonus cheques” to each of the other team members. (See Appendix A) A team of six members distributes $3300 among the other team members. A team of five members works with $2700, a team of four with $2200, and a team of three with $1700. Each student must provide a detailed explanation/justification for the bonuses that are assigned. The team contribution mark obtained by each student is based on the total value of the “bonus cheques” that they receive from their teammates. Students who choose not to complete this exercise receive a zero mark for this portion of their final grade.

The statements made to explain and justify the “bonus cheque” distribution clearly capture the essence of how people view the contributions of others. Invariably, those who contribute very little or choose not to contribute at all are given lower grades by their teammates while those who choose to develop in the team skill areas receive high grades. In most cases, strengths and weaknesses identified in the self-assessments are consistent with those that have been identified by his/her teammates.

The assessments and “bonus cheque” distribution (with justification/explanation) are submitted in a sealed envelope. They remain confidential and in the hands of the professor until the grade appeal period has expired. At that time they are destroyed. Students who wish can make an
appointment with the professor to discuss this component of their grade following the posting of the Provisional Marks.

Student Design Teams are given a significant level of responsibility for the conduct of the course. This is based on a belief that students learn and retain more when they have a sense of ownership. All laboratory activities utilize the formal training in team development as well as addressing the overall course objectives.

In order to encourage discussion of lecture material, each Design Team is required to submit a multiple choice question based on each lecture. Questions are submitted during the laboratory period following the lecture, using a laptop computer that is available in the laboratory. Both classroom observation and student comments suggest that our goal of encouraging discussion is accomplished. Any team that chooses not to submit a question is penalized through the grading system. The student’s questions provide 60% of the final examination content. They also provide a valuable, and immediate, feedback loop with respect to student understanding of the lecture material.

Given that the students, individually and collectively, have a responsibility to assist in the management of the laboratories, they must have access to their records. Team files are placed in a portable file box that is available during every laboratory session. For the remainder of the week, the files are kept in the professor’s office as a matter of convenience and to assure security. All written communication associated with the course is maintained in these files.

Each Design Team files a report for each laboratory period using a standard form. (See Appendix B) These reports require a brief outline of activities undertaken and signatures of all those who were present, together with their arrival and departure times. The reports are copied each week to provide backup with respect to the authenticity of the material in the student files. This process was initiated at the request of students who were concerned that some of their less committed classmates would sign forms from past weeks to hide their absences. Since this process was initiated, and students were informed of it, there have been no known cases of misrepresentation as it relates to laboratory reports.

Accuracy of laboratory report information is important because laboratory attendance is mandatory, with marks deducted for non attendance. In order to deal with justifiable absences, Excused Absence forms are available in the team files. (See Appendix C) Each team has one Excused Absence form per team member. Upon request, any team member can ask his/her teammates to complete a form on their behalf. If the form is submitted, there is no grade penalty assessed. Only team members may authorize an absence.

Laboratory projects include five different design/build/demonstrate projects. The projects are open ended, leaving as much design latitude as possible. Students are encouraged to be creative
and take risks. To assure that there is a minimum penalty associated with taking a risk, “raw” numbers from the grading process are ranked, with a maximum grade of 10 and a minimum grade of 7. In this way, as long as a Team participates, the worst they can get is 7 out of 10. It has been observed, however, that Teams are not satisfied with simply working to the minimum. The project titles, a short description of the “task” and one example of a project assignment sheet are presented in Appendix D.

Upon completion, all team projects are evaluated. In the case of a project that can have its performance monitored, a numerical assessment is made. This might be the average distance travelled for a rubber band powered car or the closeness to the target for an egg moving machine. These numerical data will then be ranked on the 7 to 10 scale defined above.

More subjective evaluations are undertaken by the teams. Each Design Team evaluates each of the other team’s projects using evaluation forms provided by the professor. Criteria used in the process are selected to force value judgements and comparisons. Every form must be signed by all team members to confirm their concurrence with the decisions made. Project grades are based on the evaluations, once again, using the 7 to 10 ranking. (See Appendix E)

Every component of the course contributes to the final grade. Responsibility for both learning and grading input is in the hands of the Design Teams and the students who make up the teams. For the most part, students adapt quickly. Professor/Course evaluations confirm satisfaction with the process.

Since introducing training in team development as an integral part of the course, the number of non-functional teams has dramatically reduced. Student response, both formal and informal, suggests that this is critical to their ability to adapt to the team environment.
Appendix A

Team Contribution Assessment

In the Course Outline, the following statement was made respecting individual contributions to the team effort.

“At the end of the term, each student will be required to submit an assessment of the contribution of all team members (excluding the person doing the evaluation). Both the assessment of other team members, and the thoroughness of each individual assessment will be taken into account.”

The purpose of this exercise is twofold. First, individuals who choose not to contribute to a team effort should be held to account for that decision. Those who can best assess the input by each individual are the team members. This exercise allows all team members to make their feelings known. Secondly, each of you will be required to make this sort of assessment in the “real world”. This simply provides you with some experience to build on.

PLEASE NOTE - Your assessments will be held in STRICTEST CONFIDENCE. The individual assessments will be shredded by Dr. Frye once the grade appeal period has expired. If you wish, you can make an appointment to discuss this component of your grade following the posting of Provisional Marks.

Once you have completed your report, it should be placed in a sealed envelope addressed to Dr. Frye and delivered to the “140 Reports” box in Room 107 in the Engineering Building. The reports are due December 13, 2002, no later than 16 00 h.

Your report should include:
1. your name,
2. your team name and team number,
3. the names and bonuses of your team mates, and
4. the justification for your bonuses

In essence you are being asked to assess the input of each of the other team members. Your input is not included in this assessment.

For a team of six persons, you will distribute $3300 worth of “bonus cheques” among the other five team members. A team of five persons will work with $2700 and a team of four persons with $2200 of “bonus cheques”. A team of three will have $1700. Bonuses must be in increments of $100. In other words, $0 is acceptable, but $110 is not. And remember, you MUST justify your recommendations.
Appendix A (cont)

A total of 5% of your final grade is “up for grabs” in this exercise, but there is an extra 1% available. If your average “bonus” as assessed by your team mates is between $600 and $800, you will be assigned 4% toward your final grade. If it is above that range, you will receive 5%, and if it is below, you will receive 2% or 3%. The “extra” 1% will be assigned to each person who undertakes to complete the exercise with some serious thought. This will be judged by comparing the “bonus” assigned by individuals to that assigned by the rest of the team. Past experience has shown that team mates are remarkably consistent in identifying contributors. Therefore, it is possible to receive 6% in some cases. **If you choose not to file a report, you will not receive the grades suggested by your team mates.**

130.140 Engineering Design Assessments

CONFIDENTIAL

PART A:

Team Contribution Assessment Report

<table>
<thead>
<tr>
<th>Name: (Please Print)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Number:</td>
</tr>
<tr>
<td>Team Name:</td>
</tr>
<tr>
<td>Date filed:</td>
</tr>
</tbody>
</table>

PLEASE NOTE - Your assessments will be held in STRICTEST CONFIDENCE. Dr. Frye will shred the individual assessments once the grade appeal period has expired. If you wish, you can make an appointment to discuss this component of your grade following the posting of Provisional Marks. (I am the only person to handle the material once you have given it to me. Most students have accepted my assurance of security and have been very candid.)

**COMPLETED REPORTS:** Once you have completed your report, it should be placed in a **sealed envelope** addressed to Dr. Frye and delivered to the “140 Reports” box in **Room 107** in the Engineering Building. **The reports are due December 13, 2002, no later than 16 00 h.**

Summary of Bonuses Assigned:

**For a team of six persons, you will distribute $3300 of “bonus cheques” among the other five team members. A team of five persons will work with $2700 and a team of four persons with $2200 of “bonus cheques”. A team of three will have $1700. Bonuses must be in increments of $100. In other words, $0 is acceptable, but $110 is not.**
Appendix A (cont)

In the space provided, assign the “Bonus Money” to each of your team mates (remember - $100 increments only). You must provide a detailed explanation/justification for the bonuses that you assign.

Remember an “extra” 1% may be assigned to each person who undertakes to complete the exercise with some serious thought.

PART B: Team Assessment

In the following table\(^{(1)}\), evaluate your team on a scale of 1 to 5.
(1 – never, 2 – rarely, 3 – sometimes, 4 - frequently, 5 – always)

<table>
<thead>
<tr>
<th>Item</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>We have specific and clear goals, milestones, and deadlines.</td>
<td></td>
</tr>
<tr>
<td>We try to learn from one another.</td>
<td></td>
</tr>
<tr>
<td>Everyone understands what is expected of each team member.</td>
<td></td>
</tr>
<tr>
<td>People carry out their assignments cheerfully.</td>
<td></td>
</tr>
<tr>
<td>Leadership is shared.</td>
<td></td>
</tr>
<tr>
<td>We usually consider several alternatives before we make major decisions.</td>
<td></td>
</tr>
<tr>
<td>We treat each other with respect, especially when we disagree.</td>
<td></td>
</tr>
<tr>
<td>Different opinions are valued.</td>
<td></td>
</tr>
<tr>
<td>When problems arise, we deal with people directly and not behind their back.</td>
<td></td>
</tr>
<tr>
<td>Meetings start and end on time.</td>
<td></td>
</tr>
<tr>
<td>People are good listeners - we try to understand before being understood.</td>
<td></td>
</tr>
<tr>
<td>We focus on problems, not people.</td>
<td></td>
</tr>
<tr>
<td>If we don't like an idea, we try to offer an alternative.</td>
<td></td>
</tr>
<tr>
<td>We try to solicit input from one another.</td>
<td></td>
</tr>
<tr>
<td>Everyone has an obligation to participate.</td>
<td></td>
</tr>
<tr>
<td>We usually have an agenda/plan for our meetings.</td>
<td></td>
</tr>
<tr>
<td>We keep good records of what we did and when we did it.</td>
<td></td>
</tr>
<tr>
<td>We try to have fun.</td>
<td></td>
</tr>
<tr>
<td>We always try to reach consensus on important decisions.</td>
<td></td>
</tr>
<tr>
<td>TOTAL:</td>
<td></td>
</tr>
</tbody>
</table>
Appendix A (cont)

| It is acceptable to miss deadlines. |
| People pretty much do what they want, when they want. |
| The same people consistently do most of the work. |
| One or two people usually tell others what to do. |
| We usually accept the very first solution that sounds reasonable. |
| It is best to avoid conflicts |
| We vote on all decisions, even small ones. |
| If some do not speak up for themselves their views are not considered. |
| Sometimes it is okay to get personal when disagreeing or critiquing another's ideas. |
| Side conversations are okay at meetings. |
| Our meetings are usually much longer/shorter than planned. |
| During meetings/discussions some people go off on tangents or talk at length about unrelated topics. |
| Our records are such that no one could replicate our results. |
| No one seems to be having fun … just drudgery. |
| We rarely achieve consensus and decisions are rarely made. |

TOTAL:

---

PART C: Self Assessment

In the following table\(^{(2)}\), evaluate **yourself** on a scale of 1 to 5.

(1 – never, 2 – rarely, 3 – sometimes, 4 – frequently, 5 – always)

<table>
<thead>
<tr>
<th>Results</th>
<th>Self</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>I listen attentively to others without interrupting</td>
<td></td>
</tr>
<tr>
<td>I convey interest to what others are saying</td>
<td></td>
</tr>
<tr>
<td>I provide others with constructive feedback</td>
<td></td>
</tr>
<tr>
<td>I restate what has been said to show understanding</td>
<td></td>
</tr>
<tr>
<td>I clarify what others have said to ensure understanding</td>
<td></td>
</tr>
<tr>
<td>I articulate ideas clearly and concisely</td>
<td></td>
</tr>
<tr>
<td>I use facts to get points across to others</td>
<td></td>
</tr>
<tr>
<td>I am good at persuading others to adopt a particular point of view</td>
<td></td>
</tr>
<tr>
<td>I give compelling reasons for ideas</td>
<td></td>
</tr>
<tr>
<td>I generally win support from others</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL:

---

\(^{(1)}\) Table from “Tools and Tactics of Design”, Dominick et al

\(^{(2)}\) In the following table, evaluate **yourself** on a scale of 1 to 5.

(1 – never, 2 – rarely, 3 – sometimes, 4 – frequently, 5 – always)
Appendix A (cont)

<table>
<thead>
<tr>
<th>Decision Making</th>
</tr>
</thead>
<tbody>
<tr>
<td>I analyze problems from different points of view</td>
</tr>
<tr>
<td>I anticipate problems and develop contingency plans</td>
</tr>
<tr>
<td>I recognize interrelationships among problems and issues</td>
</tr>
<tr>
<td>I review solutions from opposing perspectives</td>
</tr>
<tr>
<td>I apply logic in solving problems</td>
</tr>
<tr>
<td>I challenge the way things are being done</td>
</tr>
<tr>
<td>I solicit new ideas from others</td>
</tr>
<tr>
<td>I generate new ideas</td>
</tr>
<tr>
<td>I accept change</td>
</tr>
<tr>
<td>I suggest new approaches to solving problems</td>
</tr>
<tr>
<td>I offer solutions based on facts rather than “gut feel” or intuition</td>
</tr>
<tr>
<td>I discourage others from rushing to conclusions without facts</td>
</tr>
<tr>
<td>I organize information into meaningful categories</td>
</tr>
<tr>
<td>I help others to draw conclusion from facts</td>
</tr>
<tr>
<td>I bring information from “outside” sources to help make decisions</td>
</tr>
</tbody>
</table>

TOTAL: (2)

Table from “Tools and Tactics of Design”, Dominick et al

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Appendix B

Laboratory Report Form (with a time sheet)

Date: ________________________________

Team Number: ________________________

The undersigned were present and participated in the 130.140 laboratory exercise today. During the laboratory period the following activities were undertaken:

REPORT:

TIME SHEET:

_________________________  ___________________________  In _____  Out______
  Reporter (Print)                     (Signature)

_________________________  ___________________________  In _____  Out______
  (Print)  (Signature)

_________________________  ___________________________  In _____  Out______
  (Print)  (Signature)

_________________________  ___________________________  In _____  Out______
  (Print)  (Signature)

_________________________  ___________________________  In _____  Out______
  (Print)  (Signature)

_________________________  ___________________________  In _____  Out______
  (Print)  (Signature)

_________________________  ___________________________  In _____  Out______
  (Print)  (Signature)
Appendix C

Excused Absence Form

I, __________________________________________, wish to advise of my absence from the 130.140 Engineering Design Laboratory on _____________________________.

I have discussed my situation with my teammates and they have agreed to accept my explanation.

Date Submitted: ____________________________

Name of Absentee: ________________________ Team Number: _________________

Signature: _________________________________

Team Members

1. (Print) ____________________________ (Signature) ____________________________

2. (Print) ____________________________ (Signature) ____________________________

3. (Print) ____________________________ (Signature) ____________________________

4. (Print) ____________________________ (Signature) ____________________________

5. (Print) ____________________________ (Signature) ____________________________

To be valid, this form must be signed by ALL of the Team Members who were present on the day when the absence occurred, as well as the person who was absent. It must be handed to Dr. Frye within eight (8) days of the absence.
Appendix D

Laboratory Assignment List

Laboratory 1
- Team Building
- Team Name and Confirmation
- Laboratory Procedures

Laboratory 2
- Continuing Team Building
- File Card Tower design and construction
  Design and build a tower using file cards and masking tape. The tower must support a 20 kg load.
  Towers are ranked based on the equation
  \[ R = 2 + S(H-125)/C \]
  where:
  \( 2 \) = value assigned for having a tower to test
  \( S = 1 \), if the tower supports the 20 kg mass
  \( S = 0 \), if the tower does not support the 20 kg mass
  \( H \) = height of the tower, in mm
  \( C \) = number of cards used

Laboratory 3
- Brainstorming exercise in groups no larger than 20 students.
  Week 1, generate as many ideas as possible. 20 ideas receives 3 points, 25 receives 4 points and 30 or more receives 5 points.
  Week 2, prepare a design recommendation based on the previously generated ideas.
- Design a folding sawhorse.
  The design must be presented in freehand graphic form, on a flip chart page, using a broad nib felt tip pen. A maximum of 10 words can be used on the page. The project is conducted during the second half of laboratory 3, and is due at the end of the second week. Students evaluate other teams projects at the beginning of the following week.

Laboratory 4
- Design and build a vehicle that is powered by a rubber band provided by the professor
  Students have two weeks to design and build their vehicle. They compete for maximum distance during the third week. All teams must prepare a work plan. Each team has five minutes to demonstrate their vehicle's capabilities, with a maximum of three runs. Designs are evaluate for distance travelled (the two best distances are averaged) and critiqued by the other design teams.

Laboratory 5
- Design and build a controller for a three story elevator
  Students are provided with a bread board and a package of chips, switches and wires. They receive a short lecture on the logic required to design the system as well as an explanation of what each of their chips “will do”. At the end of the second week, they must demonstrate their design. Evaluation is based on student assessments of the performance of the device.
Appendix D (cont)

Laboratory 6
- Design and build a device to move a raw egg through a distance of 4.8 m
  This is a three week project. The egg must pass over a 2 by 6 placed half way between the start
  point and the “target”. The device cannot use any form of electricity as a power source. Students
  cannot touch the egg or the machine once the demonstration is begun nor can they “trap” the egg at
  the target point. The egg must be delivered in “marketable” condition. Performance is graded
  based closeness to the “target” and soundness of the delivered egg. Design teams evaluate each
  design against a series of criteria.

Laboratory Number 4
Weeks of February 3 to February 24, 2003
(Includes Midterm Break – Week of February 17,2003)

The Great Rubber Band Vehicle Design Project

We are in a continuing search for environment friendly, non-polluting sources of power to replace
the internal combustion engine. Over the next three weeks you will have an opportunity to
explore a much maligned alternative that some have suggested has the potential to cause concern
in traditional energy circles. (Those same people are currently in active pursuit of a patent for
their latest perpetual motion machine.)

You are about to design and construct a vehicle that is to be powered by a single rubber band. An
“official” rubber band will be supplied to each Design Team. The object of the exercise is to have
the vehicle travel as far as possible. Performance will be assessed on the “drag strip” in Room
351.

You are expected to do the bulk of the design and construction in Room 351 during class.

All vehicles will be demonstrated in the regular laboratory period on February 25, 2003 for
Section L03 and February 27, 2003 for Section L04. The order of demonstrations will be
determined by random draw prior to testing.

Constraints:
- the “motor” must be contained within the vehicle and move with the vehicle.
- each Design Team will have five minutes during which to demonstrate the performance of its
  vehicle.
Appendix D (cont)

- you will have a maximum of three test runs. Test results will be the average of the two best runs.
- you cannot “interact” with your vehicle once it has left the start line
- a run is discontinued if the vehicle goes off the terrazzo flooring in either direction. The distance travelled will be defined as the distance between the start line and the point where the vehicle “left the track”.
- a run is discontinued if the vehicle loses contact with the terrazzo flooring. The distance travelled will be defined as the distance between the start line and the point where “contact” was lost.
- the start line is defined by the rearmost portion of the vehicle. No portion of the vehicle can, at any point in time, project behind the start line
- the vehicle cannot have a mass that exceeds 4 kg
- no open flame or smoke

Workplan:
During the Lab Periods of February 4 and February 6 each team must complete a workplan of how they intend to complete the project. The workplan is to be updated each week and left in the team file in the “beer box”.

Lab Reports:
Your team is expected to file a Laboratory Report for each period during which the design and construction of the vehicle is under way.

Grade Weighting:
As far as “grade weighting” is concerned, run results will be recorded in metres and the average of the best two runs will be defined as the “distance travelled”. A minimum grade of 5 will be assigned as long as a vehicle is placed on the track (distance travelled = 0). If a vehicle actually “moves” on the track, it will receive a grade of at least 7. A maximum grade of 10 will be assigned for the vehicle that travels the greatest distance. Grades between 7 and 10 will be assigned proportionately based on “distance travelled”.

Critique Grade:
A second component of the “grade” for this assignment will be the assessment of your design by your classmates. During the “Performance” of the vehicles, each team will be required, as a team, to assess the vehicles designed and built by the other teams. A form will be provided to assist in this assignment. Those in attendance will sign the form after it has been completed indicating that they agree with the grades assigned. You will place your grading sheet in your team file.
Appendix E

Critique of Sawhorse Sketch

Critique performed by Team: ________________ Date: ________________

Team member signatures:

________________________________________________________________________

________________________________________________________________________

This critique is for the design sketch presented by Team: ____________

1. **Clarity of the sketch. (Does the sketch adequately display the intent of the design?)**
   List any details of the sketch that you feel are unclear.

2. **Safety**
   List any aspects of the design that you feel could be unsafe to the user.

3. **Meeting the problem constraints**
   List any aspects of the design that you feel do not meet the constraints of the problem.

4. **Recommended Improvements to the design**
   What improvements to the design do you recommend?
Bibliographic Information

Biographical Information

M. G. (RON) BRITTON holds degrees from the Univ. of Saskatchewan, the Univ. of Manitoba and Texas A&M Univ. He has practiced Engineering with Shell Oil, the Canadian plywood industry and Beaver Lumber, in Canada and the United Kingdom. He is registered as a P. Eng. in Manitoba and is past-President of APEGM. He holds the NSERC Chair in Design Engineering.

M. J. (JOHN) FRYE holds degrees from the University of Manitoba and has practiced Engineering with Dominion Bridge Company, Manitoba Hydro and the City of Winnipeg. He is registered as a P. Eng. in Manitoba and currently serves on the Safety Committee of APEGM. He serves on several committees for the National Building Code of Canada.