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# Systematic Team Formation Leading to Peer Support and Leadership Skills Development

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## 1. Introduction

Within a typical university environment, there are many courses that are taught in multiple sections and are multi-disciplinary. Within such settings, this paper aims to examine the role of team formation on the following: 1) the learning of students, as measured by end-of-term grades, especially the weaker students; and 2) the quality of team leaders' experiences. Two streams of research in the literature are most relevant to this study: (1) leadership skill development in engineering education; (2) teaching-learning types and methods.

### 1.1. Leadership Skill Development in Engineering Education

There is a growing consensus on the importance of leadership skills in engineering practice and education in the US and worldwide[1]. From the viewpoint of Bonasso (2001), the focus on technical skills can overlook the value of an engineering education as a foundation for becoming a successful leader in many activities that benefit society[2].

In "The Engineer of 2020. Visions of Engineering in the New Century," The National Academy of Engineering included leadership in their recommended attributes of the engineer and suggests that practice of leadership would grow in proportions as their careers advance[3]. Graham (2009) showed that leadership education is still a relatively new and under-resourced field[4]. Ahn *et al.* (2014) suggest that one of the reasons for the disproportion in leadership education lies in the shortage of research[5].

Leadership can be generally thought of as the combination of the following skills: management, team building, and creativity[6]. Wilding *et al*. (2012) attempt to arrive at a working definition of leadership specifically for engineering education purposes by conducting and analyzing surveys with a group of professional and industrial leaders on their Industrial Advisory Board[7]. A list of 12 leadership traits is identified which encompasses principles of management of self, interactions with others, and organizational effectiveness. In particular, these traits include "(3) Takes initiative rather than waits for assignments"; "(4) Follows as well as leads"; "(7) Receives criticism and makes changes where appropriate"; "(8) Demonstrates a good attitude on life and is pleasant to work with"; "(9) Is an effective communicator, including being a good listener"; "(10) Gives honest feedback to others and helps them succeed in their responsibilities"; "(12) Is culturally sensitive and works effectively with people from diverse backgrounds". Notable in this list is the prominence of teamwork skills. Many leadership skills are equally well and commonly labeled teamwork skills.

A more formal empirical study on definition and assessment of leadership traits was documented in Ahn *et al.* (2014)[5]. Results confirm that engineering leadership is similar to leadership as defined in business and organizational management and the leadership traits identified in the study align with those found in traditional leadership literature. For example, being proactive, motivated, and courageous and having a vision and common goal are mentioned by Farr *et al.* (1997) [8] and Hall and Seibert (1992) [9].

It is also worthy of noting that these traits echo two of the non-technical ABET Student Outcomes a-k[10]: (d) "an ability to function on multidisciplinary teams", and (g) "an ability to communicate effectively". While the general framework of team-based learning we are to adopt in this study naturally reflects outcome (g), we explicitly structure the team formation according to outcome (d), i.e. enforcing a multidisciplinary team composition.

### 1.2. Team-Based Learning

It becomes clearer based on the previous discussion that leadership skills (traits) are presented in various forms of teamwork skills. It is thus no coincidence that we observe a growing practice and research on team-based pedagogy in engineering education. As suggested in Michaelsen *et al.* (2014)[11], Team-Based Learning (TBL) [12-16] has proven to be a practical and effective strategy for addressing these challenges and transforming our classrooms into a more enjoyable experience for teachers and students alike.

Four foundational practices were also identified as essential for implementing TBL[12-16]: 1) strategically forming permanent teams (5-7 members per team), 2) ensuring student familiarity with course content by utilizing a Readiness Assurance Process, 3) developing students' critical thinking skills by using carefully-designed, in-class activities and assignments and, 4) creating and administering a peer assessment and feedback system. It was also suggested that the key to a successful team formation and management is (i) to ensure each group contains members of diverse points of view and to minimize potential disruptions from cohesive subgroups such as pre-existing friendships; and (ii) the team must remain stable over a long enough period for the team-development.

In comparison, a cooperative-learning (CL) setting involves smaller groups (2-4 members) and runs non-permanent teams. Most CL tasks are structured to be completed within one class period, and can be handled by groups with 2-4 members. Smaller groups are both more efficient and more effective than larger groups in dealing with small-scaled tasks and projects. For a thorough comparative study on various types of learning in small groups, which include collaborative learning, cooperative learning and problem-based learning, see Davidson and Major (2014) [17].

We adopt a mixture of team-based and cooperative learning strategies to best suit our pedagogical needs. In particular, we adopt permanent team (a TBL feature) with 3-4 members each team (a CL feature), and design experiments to test the multidisciplinary team structure against team formation with likely cohesive subgroups.

## 2. Project Goal and Framework

The design and implementation of an experiment in team formation is proposed in multiple sections of an Engineering Economic Analysis course with a high content of teamwork. In the treatment group, the students are placed in teams based on academic ability. Each team is balanced by having a member from each of the "Great" (G), "Above Average" (AA), "Average" (A), and "Below Average" (BA) category. Each team is also formed to be multidisciplinary, to include at least two engineering disciplines, out of the four disciplines offered at Quinnipiac University. In the control group, the students form their own teams. Team formation in the Control group will most likely be based on previous familiarity of being in same courses in the past, likely as a result of being in the same engineering discipline.

The primary hypothesis is that class average in the treatment group will be higher. This is especially true for the BA and A students who will have easy access to stronger team members in study groups or for additional support. The secondary hypothesis is that the team leaders in the treatment group will gain more skills in leadership, motivation, and conflict resolution as the team members have little to no prior knowledge about each other.

The proposed Engineering Economic Analysis course is one of only three engineering courses during the entire engineering curriculum at Quinnipiac University that is common to all four engineering disciplines offered. Among the three common courses, it is the only one with a technical content, requiring analytical work and problem solving. The importance of Engineering Economics in Engineering Curricula has been carefully examined in literature, see e.g. Zoghi (2015)[18], and the cross-disciplinary nature of the classes were recognized and utilized in teaching practice through team-based (Martinazzi, 1998)[19] and project-based (LeBlanc and Boulanger, 2014)[20] methods. Commonality across the engineering programs ensures a large class size and multiple sections. Having multiple sections, and a sufficient sample size in each section, provides the opportunity for control and treatment groups within a design of experiment framework, leading to statistically significant conclusions. A comparative study between multiple sections in particular between traditional and online delivery was reported in Wilck and Kauffmann (2013) [21].

This course is scheduled for engineering sophomores (and selected freshmen) instead of seniors as documented in some literature[2]. We believe it is advantageous to start learning and sharpening teamwork and leadership skills as earlier as possible and engineering economics serves as a great platform. Such a belief, has been noted a century ago by a renowned engineer John Harford [21] that engineering and economics “help to develop the very valuable habit of thinking in terms of groups rather than of individuals”, where the direct connection between engineering economics and team/group thinking is explicitly recognized and valued.

At the time of writing this manuscript, the course is underway. Therefore, throughout this manuscript, the design process, the course framework, and the proposed analysis are described in detail while the results are discussed based on instructor observations and graded material thus far.

## 3. Design and Analysis

When it comes to curricular assessment, this particular course is used for formative assessment of several ABET outcomes, including (d), “an ability to function on multidisciplinary teams”, and (g), “an ability to communicate effectively”, which as discussed above, can be interpreted as teamwork and/or leadership skills. As such, a great emphasis is placed on teamwork and communication skills. There are grading elements incorporated within the syllabus to reflect this. A large portion (26%) of the students’ end-of-term grade is team-based, consisting of the following: (i) case study analyses and presentations, (ii) problem solving sessions for the class, and (iii) a project.

(i) For case studies, the student teams are assigned an end-of-chapter case study from the text book. The team spends 15 to 20 minutes in front of the class to present the case, their assumptions, and their analysis in answering the case questions.

(ii) After every two chapters covered from the text book, there is a problem-solving session to ensure students are keeping up with the material. In these sessions, all the students in the class are expected to have attempted the assigned end-of-chapter problems on their own. However, one student team is assigned to take over the class and solve (and explain) any questions that any student in class has difficulty with. Such an arrangement facilitates the notion of "students teaching the students" as quoted in Martinazzi (1998)[19].

(iii) The final element of the team-based grade is a project. Each team does a project management activity and perform a team presentation on their analysis of this activity.

For all graded team-based components, CATME surveys are used for fair assessment of the individual students' roles. CATME is a short, web-based survey that collects and analyzes self- and peer-evaluation feedback. A behaviorally-anchored rating scale is utilized to assess contributions of each team member in five areas based on the team effectiveness literature (Ohland *et al.*, (2012)[23]. The grade for each team-based component is multiplied by the CATME factor for each student and that is the score entered for the student. As such, if a student does not pull his/her weight, s/he is penalized by the rest of the team and gets a lower grade than the rest of the team members. Conversely, if a student goes above and beyond the norm, s/he is recognized by the teammates and gets a higher grade than the original team score.

It should be noted that another component of the course, Problem Sets, account for 18% of the final grade. The four problem sets are submitted on an individual basis. However, the members of the team with the highest average each receive a bonus point. This serves to encourage the team members to work with each other. In well-functioning teams, the strong members have an incentive to help the weaker members and the weaker ones have easy access to guidance.

There are two instructors for the three sections. Instructor 1, Section 1, is designated to be a control group, consisting of 16 students, placed in four teams of four. Instructor 1, section 2, is designated to be a treatment group, consisting of 14 students, placed in two teams of three and two teams of four. Instructor 2 only has a treatment group, consisting of 21 students, placed in four teams of four and one team of five. Data from Instructor 2 will complement the treatment group of Instructor 1. As the project was being designed, we wanted to minimize the effect of having two different instructors. As such, we assigned Instructor 1 to have both a control group as well as a treatment group, as opposed to having two control groups and leaving the treatment group to Instructor 2. Given the fact that Instructor 2 has a complementary section of the treatment group, adding to the sample size of the treatment group, we made the larger of the two sections of Instructor 1 to be the control group.

The two instructors use the same teaching material and follow the same teaching methods. Every attempt is made to stay as consistent as possible across the three sections. The 75-minute class is conducted twice-a-week for 14 weeks and the two instructors compare notes before and after each class. The same text book is used and the cases, end-of-chapter problems, problem sets, midterm test, and final exam are common to the three sections.

Students have randomly selected any of the three sections based on time slots fitting their schedule. Prior to the start of term, the full class roster for all three sections was shared with an instructor from each of the four engineering programs for the purpose of categorizing students into G, AA, A, and BA. The discipline instructors who were chosen were those who have had direct contact with the sophomore students and have taught them at least one discipline-specific course. As a result, they were able to assess the students' academic ability and to make an educated decision on which of the four categories each student can be placed in. Once the categorization of the students was complete, teams of four were made by the instructors in the two treatment groups to include a student from each of the four categories, G, AA, A, and BA, in order to have balanced teams. Another constraint the instructors used when forming the teams was to include at least two engineering disciplines in each team. In sections 2 and 3, all teams have representation from at least two engineering disciplines. In the control group, the students were asked to form their own teams; the student categorization and their disciplines are noted by the instructor after the fact. The noting of these facts is solely for the purposes of the experiment, and the follow-up analyses, and has no bearing on the team formation. In the control group, the four teams that were formed by the students are actually all multidisciplinary and include members from at least two engineering disciplines.

At the completion of the semester, three comparisons will be made between the student grades in the control and treatment groups. The first two comparisons are closely-related and they are the overall class average grade as well as the average grade for the BA and A students. We hypothesize that the overall average grade in the treatment group will be higher because the average grade for the BA and A students will be higher. Those students who are categorized to be BA or A now have access to two other students who are G or AA. Team-based learning will aid in their learning process as the weaker students work closely with strong students and can seek help when they run into difficulties. We expect the average grade for the G and AA students to remain unchanged when comparing the control and treatment groups. The third comparison is the grade variation within the control and the treatment groups. Because we expect the average grade for the BA and A students to be higher (while the average grade for the G and AA students to remain the same), the range and standard deviation across the treatment group teams is expected to be smaller than in the control group teams.

Thus far in the course, there have been several graded elements, worth 55%. These two are a team project, three individual problem sets, the presentation of the team's analysis of a case study, and the midterm test. For the team project, a CATME survey was posted for the students. The results from the team project, the CATME survey, the first three problem sets, a case study analysis, and the midterm test are displayed in Tables 1, 2, 3, 4, and 5 respectively. The results are still at the preliminary stage and statistical analysis do not result in significant differences. However, the general trends are in-line with our stated hypotheses; in all cases, the grade is higher in the treatment group. In the case of the CATME results (Table 2), it should be noted that a smaller deviation is desirable as it indicates more of an equal workload, and therefore peer satisfaction, across the team.

Table 1: Comparison of team project grades between control and treatment groups

| | Section 1 – Control | Sections 2 and 3 combined - Treatment |
|---|---|---|
| Sample size | 16 | 35 |
| Average | 88.46% | 94.78% |
| Range | 72.6-97 | 69.5-100 |
| Standard Deviation | 7.51 | 6.98 |

Table 2: Comparison of student feedback on team dynamics during project work

| | Section 1 - Control | Section 2 and 3 combined - Treatment |
|---|---|---|
| Average standard deviation for all teams | 0.040 | .034 |

Table 3: Grade comparison of first three problem sets, control and treatment groups

| | Section 1 – Control | Sections 2 and 3 combined - Treatment |
|---|---|---|
| Sample size | 46 | 103 |
| Average | 90.65% | 92.36% |
| Standard Deviation | 1.93 | 3.04 |

Table 4: Grade comparison of case study analysis

| | Section 1 – Control | Sections 2 and 3 combined - Treatment |
|---|---|---|
| Sample size | 12 | 23 |
| Average | 93.67% | 96.78% |
| Standard Deviation | 1.25 | 1.61 |

Table 5: Grade comparison of midterm test, control and treatment groups

| | Section 1 – Control | Sections 2 and 3 combined - Treatment |
|---|---|---|
| Sample size | 16 | 35 |
| Average | 67.81% | 70.86% |
| Standard Deviation | 8.33 | 9.41 |

Regardless of the process for forming the teams, selecting the team leader role is left to the student teams. At the start of term, the two instructors ask their respective students to have team rules and to select a team leader. This role should rotate every three weeks to provide everyone with a chance to experience the leadership position. At the end of the term, each student will individually submit a reflection that discusses this experience. They will also individually complete a short survey, consisting of a number of close-ended questions with answers on a Likert scale for the purposes of evaluating their experience and learning. This reflection contributes to 4% of the students overall grade at the end of the term. Using the survey questions, a comparison will be made between the team leaders in the control and treatment groups. Our hypothesis is that the team leaders in the control group will learn more as they have to play a larger role to facilitate team tasks, act as a leader, motivate everyone, and resolve conflicts. This is mainly due to the fact that the team members do not know each other from before and have been put together by the instructor.

The results of the survey will be used to test the hypothesis that team leaders in the treatment group will gain more skills in leadership, motivation, and conflict resolution. In addition to assessing the quality of learning that each student experiences when fulfilling the team leader role, the survey also needs to capture the possible foregone opportunity to work on a multidisciplinary team. If the students form their own teams, there is a high chance they do so based on prior familiarity with each other. This is likely based on having had courses together which likely results from being in the same discipline. As mentioned before, instructors form teams to be balanced and multidisciplinary. But when the students form their own teams in the control group, neither one of these two criteria is used as a design parameter in team formation.

## 4. Future Work

A multi-section, sophomore-level, core course, common to all four disciplines of engineering at Quinnipiac University is used to run an experiment to test two hypotheses. There is significant emphasis on teamwork in the course and 26% of each student's end-of-term grade is directly affected by their team members. In the design of this experiment, one of the three sections is the control group and the students in this section are asked to form their own teams, with no input from the instructor. The other two sections are the treatment group and the instructors form the student teams. Team formations in the treatment group are based on two criteria: 1) the academic quality of the students, pre-determined through consulting a faculty member who has had the student in a class before, and 2) the multidisciplinary nature of teams, by having representations of at least two of the four engineering disciplines offered at Quinnipiac University. Regardless of the team formation process, the instructors have no input into team leader selection or team rules. Teams select their own leaders and this role rotates throughout the semester to ensure everyone experiences this responsibility.

The primary hypothesis is that class average in the treatment group will be higher. This is especially true for the A and BA students who will have easy access to stronger team members in study groups or for additional support. The secondary hypothesis is that the team leaders in the treatment group will gain more skills in leadership, motivation, and conflict resolution as the team members have little to no prior knowledge about each other.

This course is ongoing and the results are not finalized. However, the preliminary analysis is promising and the first hypothesis about the treatment group having a higher class average than the control group currently holds. Once the hypotheses are tested at the end of the semester, and assuming they both hold, other classes with a high level of teamwork can follow suit to form balanced and multidisciplinary teams. This requires an additional burden for the course instructor as s/he has to reach out to other instructors and gain insight on each student's academic ability. However, after this information is used to systematically form teams, the learning experience of the students is enhanced and goes beyond the course-specific, theoretical knowledge of the course. Students gain maturity as they learn about leadership, motivation, and conflict resolution. The concepts described can be easily transferred to courses with a high level of teamwork, whether it is an engineering course or in any other discipline.

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