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Pre-defined Roles and Team Performance for First-year Students

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Abstract. A framework for managing and guiding student teams in a first-year engineering course is compared to less structured but commonly used methods. In the new framework, students take on rotating roles during laboratory projects throughout the semester. Furthermore, teams submit three versions of each report: rough draft, draft, and final. Finally, students complete peer evaluation on-line. On-line student and faculty surveys and multiple focus groups were used to evaluate the framework, which was employed in 3 sections of a 16 section first-year engineering course. Results indicate that, compared to the other common team scenarios, the framework results in improvements in students' self-appraisal of their teaming abilities at the end of the semester, students writing a greater variety of laboratory report sections, student teams more quickly entering the "performing" stage of the team adjustment phases, and more students taking on a leadership role at least once during the semester. The framework produced no reduction in free riders or increase in laboratory report quality, at least as reported by students.

Keywords: Teamwork; Designated roles; First-year; multidisciplinary

Introduction

Engineering students should work in teams in college because most working-world engineering is done in teams. Unfortunately, student teams are different from working-world teams, especially with regard to free-riders, leadership, and experience. Free-riders are people who try to ride a bus without paying. In working-world teams, free-riders are underperformers who risk losing their job when they are discovered. Student teams are much more likely to include free-riders than working-world teams, where they only risk getting a lower grade--if the instructor is able to identify them.

A boss is a working-world leader with real control: able to assign work tasks and influence hiring, firing, promotions and raises. Student teams do not have a boss; at best they have a student leader who may be a planner, meeting scheduler or facilitator, task assigner, mediator, the link between group and instructor, and/or work collector or collator. The instructor may want all team members to rotate through the leadership role.

The final major difference between student and working-world teams is the level of experience. Working-world team members have proven skills and experiences appropriate to the task at hand. Student team members learn skills as they go along.

Over multiple years teaching an introductory Engineering course with significant team activities, the primary author has developed a framework for managing teams that helps students deal with these issues. The goal of this paper is to introduce the framework and compare it to typical teaming frameworks used in an introductory Engineering course. The remainder of this paper consists of background, a description of the framework and comparison study, results and discussion, conclusions, and references.

Background

A good engineering designer must be able to work on multidisciplinary teams (Kojmane & Aboutajeddine, 2016). Unfortunately, though team-based learning has been studied extensively in other disciplines, few studies have been completed with engineering students (Najdanovic-Visak, 2017). Recent studies with engineering students point to the effectiveness of team-based learning in general (Najdanovic-Visak, 2017; Samsuri 2017), but do not explore the relative effectiveness of different frameworks for team-based learning.

New teams may go through an initial period of adjustment. According to Tuckman new groups go through four phases: Forming, Storming, Norming, and Performing (Tuckman, 1965). During the Forming phase group members try to size up each other, find the limits of acceptable group behavior, and clarify the group task (Eide et al., 1998). In the Storming phase, there may be disagreement among team members as each slowly comes to terms with solving problems in a new environment, i.e., the new team. Things get better in the Norming phase. Ground rules and team member roles are agreed upon. Members begin to see how they can work together to accomplish the group task. The final phase is Performing. The team is now "firing on all cylinders" and significant work is accomplished to complete the group task. It is crucial for team members to realize that all phases may be necessary ones, but to work through the first three as quickly as possible to reach the performing phase.

Several studies have examined collaborative assignments in the classroom. The contributions of Shuman et al. (2005), Dym et al. (2003, 2005), Felder and Brent (2001), Smith et al. (2005), and Barrick et al. (1998) provide a summary of how to instruct students using collaborative projects. Many times instructors use teams in an academic environment without much thought on how the development of teams in their course influences the students' abilities to learn the material. Student teams are formed with minimal guidance on how to work together as a team, build consensus and resolve any conflicts. This creates a missed opportunity on the instructor's part, i.e., failing to capitalize on the learning that the students can gain on group dynamics and team collaboration.

The social aspect of engineering education is emphasized in ABET's general engineering criteria, to prepare students to create engineering solutions that can have a positive global and social impact. In order for students to achieve this, it is necessary for the students to be able to work on multidisciplinary teams utilizing effective communication skills. Developing teamwork skills is not only important in an academic environment, but also to prepare students for the professional work environment. Developing teamwork skills is key to students' success on future collaborative projects (Barrick et al., 1998).

Smith et al. emphasize that there are five key elements in creating successful collaborative learning experiences for the students (Smith et al., 2005). These elements are positive interdependence, face-to-face interaction, individual accountability, developing teamwork skills, and group processing. Positive interdependence relies on the belief in the group that one student cannot succeed unless the group succeeds as a whole. This is what is often referred to as the sink or swim mentality. In addition to positive interdependence, it is also important to incorporate face-to-face interaction into collaborative assignments. This allows students to discuss their strategies for success in completing their projects.

In terms of developing individual accountability, it is important that team members hold each other accountable for creating quality work. Smith et al. (2005) suggest rotating the required roles for each project amongst the team members and making sure that every member of the team has an equal say in the team decision making. As students use this method to develop individual accountability, students inherently gain teamwork skills. It is also essential that groups process the results of their collaborative work, and emphasize continuous improvement in what the group is able to accomplish, as well as their ability to work together. Smith argues that the five elements previously discussed assist in creating a successful collaborative environment.

Another aspect of fostering successful teams is helping students manage diverse abilities and skills. Having a diverse range of abilities within a group of students is very important in team formation and should be maximized when possible (Dym et al., 2003). There are inherent difficulties for students working on a team composed of weaker students, but a team of students with higher academic abilities also struggle. According to Felder, teams of high-achieving students often have difficulty collaborating, communicating and working together to achieve their common goal. It is also important that the team hold positive beliefs about their own capabilities and their ability to work together. Having a belief in the efficacy of the team increases the cohesion and satisfaction of the team (Dym et al., 2005). While some questioning is important for group productivity, so one student does not dominate the activity, a pervasive negativity towards others' contributions will keep the team from being successful at any task (Felder and Brent, 2001). At the same time, it is important that teams develop a strategy to compensate for any differences in personalities as they form a team. This strategy is essential to their ability to effectively work together.

Finally, it is crucial that the complexity of the collaborative assignment given to the students is considered when using team-based activities in the classroom. It is important for the project assigned to be complex enough to require the work of the entire team and challenge the students that are involved (Shuman et al., 2005). Time limits and deadlines that encourage the assignment to be completed through collaboration are essential when completing a team project. If one student can accomplish the task on their own, then there is no need for the team to work together.

Several researchers have written about the use of assigned roles for student teams. For example, Schaffer and Kimfong (2006) explored the advantage of requiring students in a senior-level course to assign and define roles on teams and found that students who were required to take on and rotate specific roles had more interdisciplinary learning than those who did not, but that students also tended to work across roles even after roles were specifically assigned. Prince et al. (2011) note the use of assigned roles in teams but do not specify which roles they used in freshman courses.

With these theories and observations in mind, we explore the effects of student role assignment, role rotation, and a draft writing requirement on the performance of student teams in a first-year engineering course. This framework of assigned roles provides a way of evenly distributing the work between teammates, to prevent group conflict and address students that do not fully contribute to the group activities. Other literature provides guidelines on how to deal with this lack of student participation after the team has attempted to complete a group activity (Felder and Brent, 2001). The framework studied here addresses these concerns before the team begins an assignment, with a clear equal division of labor among the group members. This results in each member being essential in the completion of each final product, and the group developing an understanding that the group's success is dependent on each student fully participating.

Teaming Framework & Study Design

The College of Engineering at Rowan University had five engineering majors: Biomedical, Chemical, Civil & Environmental, Electrical & Computer, and Mechanical when this study was performed. Students declare their major when applying for admittance. The first-year curricula of the five majors are similar and all students take a multidisciplinary two-semester Introduction to Engineering course.

Students in the first-semester Introduction to Engineering course work in teams to complete a number of laboratory activities resulting in multiple team-authored reports. In Fall 2014 teams in three sections of approximately twenty-five students each were assigned to Treatment A and teams in thirteen similarly sized sections were assigned Treatment B. In Treatment B, faculty of varying experience and ability developed their own frameworks for forming, managing, and evaluating teams. This makes the experiment somewhat un-controlled, but there was no way to create a uniform framework in the Treatment B sections.

The sixteen sections had 12 different professors. Professor Everett used Treatment A. Professors Morgan and Mallouk taught two sections each, using Treatment A in one and Treatment B in the other. The remaining nine professors used Treatment B in eleven sections. Professor Everett had over 20 years' experience teaching freshman through graduate level courses. Professors Morgan and Mallouk were both instructors in their second year of teaching primarily first and second-year courses. The remaining professors included professors, instructors, temporary faculty, adjuncts, and teaching fellows (graduate students) with a wide range of experience.

All sections of the Introduction to Engineering course used the same online web-book, customized for the course {Everett et al., 2014). It included an example laboratory report and a detailed description of the format and sections to be used (Title Page, Abstract, Introduction, Background, Materials and Equipment, Procedures, Results and Discussion, Conclusions, References, Appendices).

In Treatment A teams are formed by the professor based on Learning Connections Inventory (LCI), gender, and major. The LCI is a learning styles inventory based on the Interactive Learning Model (Johnston, 1996). The LCI uses four styles to describe how an individual prefers to learn: Sequential, Precise, Technical, and Confluent (Johnston, 1997). Teams are selected to distribute learning styles as evenly as possible. Each team of 5 students has 0, 2 or 3 female members, to avoid isolating a single female on a team of 5, except in the case where only 1 female is enrolled in a section. Students are assigned to teams so that majors are distributed as widely as possible; ideally, each team has 5 different engineering majors.

Students do not create or sign a team contract. They are given a handout that defines roles they will perform for each lab:

- Before the laboratory
    - Literature reviewer
- During the laboratory
    - Leader
    - Data collector (Laptop or notebook)
    - Operator (physically conducts the lab, with assistance from others as needed)

- After the laboratory (Report Writing)
  - o Section writer (different ones for each report)
  - o Compiler
  - o Reviewer.

The complier and reviewer roles are described three paragraphs down.

Students are required to select different roles for each laboratory so as to take on as many different roles as possible. By having students vary roles and section-writing, they learn more skills and have less opportunity to “settle” into certain roles. For example, every student completes a literature review and uses Excel to enter and analyze data.

Treatment A is designed for teams of 5. Each laboratory session is completed with a leader, 2 students physically conducting the lab, and 2 students recording and analyzing data on the fly; thus, Treatment A may allow for an effective use of larger teams.

To sponsor individual accountability, teams submit three versions of each report:

- The Rough Draft contains the raw sections as created by each section writer and combined by the compiler with each section's author's name placed next to each section title;
- The Draft Report is the report after the compiler has addressed grammatical and spelling errors, style issues, and missing information (the compiler may send sections back to original author for a rewrite); and
- The Final Report is the report after the reviewer has corrected errors and omissions left by the compiler.

Professors only grade the final report, but may examine earlier versions to look for evidence of free-riding and poor performance, such as missing or poor sections, or poor compiling or reviewing.

Students also identify their roles and evaluate themselves and their team members online. The peer evaluation consists of a numerical grade adjustment plus verbal justification. The average, maximum, and minimum of the peer grade adjustments are provided to each student before the next team activity, providing students with feedback that may lead to an improved effort on future team assignments. Peer evaluation results are used at the end of the semester to modify laboratory grades up to 10 % up or down.

In all three sections, the professors used class time to introduce students to teamwork: 15 45, and 80 minutes, for the primary author and Professors Morgan and Mallouk, respectively. Each professor also provided further guidance in class as needed over the semester: 15, 30, and 50 minutes, respectively.

Professors Morgan and Mallouk used Framework B-1 in their Treatment B sections. In the B-1 Framework, teams are formed as in Treatment A; however, no pre-defined roles are supplied or required. Students are given a handout developed by R.M. Felder and R. Brent and reported by Oakley et al. that outlines team policies and responsibilities including suggested roles and procedures for completing group work (Kaufman et al., 2000). Team members create and commit to a Team Expectations Agreement, develop their own roles, and fill out a peer review form on paper after each laboratory report. The peer review form was based on the survey developed by Kaufman et al. (2000). Peer evaluation results were used to modify laboratory assignment grades as described by Kaufman et al. (2000). In their B-1 sections, the two professors used the same amount of class time as they used in their Treatment A sections to introduce students to working in teams: 45 and 80 minutes, respectively. They also used the same amount of time to follow up over the semester: 30 and 50 minutes, respectively.

In the remaining 11 Treatment B sections (B-2), professors used a variety of methods to form, manage, and evaluate teams, based on their past experiences. In 4 sections, students were allowed to form their own teams. In the other 7, professors formed teams using major (6 sections), LCI (3 sections), gender (2 sections), and/or schedule (3 sections). In one section, the CATME survey for team formation was used (CATME, 2015). In seven of the sections a handout was given to students that provided guidance on working in teams. In the other four sections, no handout was provided. In five of the sections, students were required to develop and commit to team contracts, with little or no guidance from the professor. In the other six sections, no contract was required. In all 11 sections, professors used class time to introduce students to working in teams: ranging from 15 to 100 minutes and averaging 48. Follow-up time over the semester ranged from 0 to 200 minutes and averaged 44.

The Treatments are compared using: (1) a student survey; (2) focus groups conducted in Professors Morgan and Mallouk's four sections at the end of the semester; and (3) a professor survey. The survey questions were developed jointly by professor Everett and reviewed for clarity and consistency by professors Morgan and Mallouk. The student survey was completed online by 217 of 366 students, 59 %. The faculty survey was completed for all 16 sections, 100 %. Fifty students from Professor Morgan's sections (98 %) and 37 students from Professor Mallouk's sections (84%) attended focus sections.

Statistical analyses were used to evaluate student survey results. T tests were conducted to evaluate differences in mean responses. The Chi-squared Goodness of Fit test was used when non-parametric tests were deemed more appropriate.

The focus groups were conducted in a somewhat unique manner. Students formed 4 or 5 groups of 4 to 5 students each. Professors made sure that the groups were not similar to the teams they used during the semester. Each student in a group was responsible for recording the group's discussion on one of five questions (see Appendix). As a class, each question was then discussed in more detail, to identify the differences in responses. Notes were taken to record the conversation, and the student's notes were collected. The focus group questions are:

1. What was your experience working on teams before coming to college?
2. What was your experience working on teams in this class? How did it compare to your other college courses this semester?
3. Describe a time that you took on a leadership role in your group this semester?
4. Describe your team's method of editing a lab report? How effective was it?
5. How long did it take for your team to work successfully as a group? Describe what your team was successful at accomplishing? Describe what your team was unsuccessful at accomplishing? Did you meet in person, and if so, how often?

Results and Discussion

The three Treatment A sections were compared to all 13 Treatment B sections. Student quotes provided in this section are from the focus groups held in Professors Morgan and Mallouk's four sections.

Students were not assigned to sections of the first-semester Introduction to Engineering course based on general academics or teaming abilities; thus, sections were expected to NOT differ significantly at the start of the semester. Two checks were made. The number of times students worked on a team to create a major laboratory report before college is given in Table 1. Over 30 % of the respondents reported no team reports, indicating the importance of teaching students about team work early in their college career. There was no significant difference between students in Treatments A and B (A/B: average=6.94/5.66; standard deviation=9.20/10.4; p=0.365). The large standard deviations are due to a relatively small number of student reporting very high report numbers. One student claimed to have worked on 50 team reports! It is possible that some students counted all team assignments, not just reports. Students were also asked to self-appraise their ability to work in teams at the start of the semester. The student responses were converted to numerical values: "Very Poor" = 1; "Poor" = 2; "Average" = 3; "Good" = 4; and "Excellent" = 5 to estimate averages and standard deviations and conduct statistical tests. There was no significant difference between Treatment A and B students (A/B: average=3.7/3.6; standard deviation=0.67/0.77; p=0.231). Based on report number and teaming ability Treatment A and B students were not significantly different at the start of the semester.

Table 1: Number of times students worked on a team to create a report before college

Number of Reports	Number of Students Giving Response
0	73
1	23
2	18
3	17
4	18
5 to 10	42
>10	32
Total	*223*

The average self-appraisal of teaming ability of ALL students increased significantly over the semester, from 3.6 to 4.3 (Start/End: standard deviation=0.74/0.66; p=0.000), indicating the students' entire first-semester experience had the expected positive effect. If Treatment A is a more effective method of teaching students to perform well on teams, one would expect Treatment A students to end the semester with a higher self-appraisal of their teaming ability. This was the case. Treatment A students self-appraised their teaming abilities slightly higher (statistically significant) at the end of the semester compared to Treatment B students (A/B: average=4.4/4.2; standard deviation=0.60/0.68; p=0.049). This better self-appraisal occurred despite writing slightly fewer reports (4.1 versus 4.3), serving on larger teams (4.7 versus 4.0), and populating larger sections (25.3 versus 23.2) in their first-semester Introduction to Engineering course. Furthermore, this difference occurred despite the fact that the treatment only occurred in only 1 of 5 courses each student took that semester.

Of the overall observations from the Freshman Engineering Clinic focus groups, there are team examples that stand out. The first example is a team in Treatment B-1. One team member, who was an underperformer, was dominating the work of the entire team. Since their work was not meeting the requirements of the course, the team's grades were suffering. Unfortunately, this student was also a difficult personality to work with, while at the same time not producing quality work for the team. Since roles were not assigned in this Treatment, this student insisted on completing the Experimental Procedure and Results and Discussion sections for each report, worth the most points, and as a result brought the team's grade down. If this team had been in a Treatment A section, this student would have been required to write different sections for each lab. The compiler and reviewer would have also improved the student's sections.

The best educational practices obtain good results without requiring a different level effort from students. Table 2 is used to show students' self-appraisal of the effort they expended in laboratory-related team work in their introduction to engineering course. The student responses are converted to numerical values: "Very Weak" = 1; "Weak" = 2; "Average" = 3; "Strong" = 4; and "Very Strong" = 5 to estimate averages and standard deviations and conduct statistical tests. The average for students in Treatment A is not significantly different than Treatment B's average (A/B: average=4.1/4.0; standard deviation=0.62/0.78; p=0.463).

This indicates that the significantly higher end of semester ability is not due to a higher level of student effort.

Table 2: Student self-appraisal of level of effort in laboratory-related team work

Answer Options	Treatment A	Treatment B
Very Weak	0	1
Weak	0	2
Average	11	33
Strong	36	76
Very Strong	18	45
Total	*65*	*157*

One objective of Treatment A is to motivate students to write different report sections. Students were asked how many different types of report sections they wrote over the course of the semester in their first-semester Introduction to Engineering course. The average is significantly higher for students in Treatment A (A/B: average=6.82/5.63; standard deviation=2.34/2.75; p=0.001), even though Treatment B teams were smaller and wrote more reports. Furthermore, 42 % of Treatment B students wrote 4 or fewer different sections and only 35 % wrote 7 or more. Contrast this to Treatment A students; only 16 % wrote 4 or fewer while 56 % wrote 7 or more. This indicates that Treatment A compelled students to write different sections, which should help them with future report writing. Surprisingly, though required to edit other students' work, Treatment A students reported less editing of sections written by other students, but the difference was not significant (A/B: average=2.27/2.10; standard deviation=1.82/1.35; p=0.435). Some Treatment B students may have doubled up on editing duties (multiple students editing the same work), something that was not encouraged in the Treatment A framework.

Another observation from the Freshman Engineering Clinic focus groups was from a student on a team in a Treatment A section. The student was pleased that team roles were pre-defined and rotated, as they believed that in a less structured environment they would have ended up doing most of the work.

Treatment A gives students a structure they use to responsibly conduct labs and write, compile, and review reports. Consequently, Treatment A is expected to accelerate teams to the point where they perform, rather than form, storm, or norm (Tuckman, 1965). Student estimates of when their team started performing are given in Table 3. The student responses were converted to numerical values: "First major report" = 1; "Second major report" = 2; "Third major report" = 3; "Fourth major report" = 4; and "After the fourth major report" = 5 to estimate averages and standard deviations and to conduct statistical tests. An answer of "My team never performed" was taken to indicate that a group had structural problems that could not be overcome; such responses were not used to calculate statistical parameters. The average for students in Treatment A is significantly lower (A/B: average=1.60/2.00; standard deviation=0.78/1.09; p=0.002), indicating that students in that Treatment believed their teams reached a high level of performance sooner that Treatment B students. The guidance and structure provided by Treatment A may have produced this result; however, student comments in the focus groups were similar between Treatments A and B-1. For example, one focus group in Treatment A reported: “It took only 1 to 2 activities to get used to our group members. The first lab, the solar lab, was when we found success in working together.” And a group in Treatment B-1: “For the first lab, no one really knew each other or what each other could do. As we progressed, everyone quickly learned what everyone was capable of doing, and those abilities were capitalized on.”

Table 3: Major lab report on which laboratory teams began performing

Answer Options	Treatment A	Treatment B
First major report	27	60
Second major report	20	45
Third major report	10	34
Fourth major report	1	4
After the fourth major report	0	8
My team never performed*	5	3
Total	*63*	*154*

The three Treatment B students that claimed their team never performed are in three different sections; thus, they are each the only member of their team feeling that way. Perhaps they were disgruntled or had higher standards or expectations than their team members. The five Treatment A students that claimed their team never performed are in three sections: 1, 2, and 2 per section. It could not be determined if the two pairs were on the same team.

Treatment A forces teams to create and submit a record of each member's contributions, i.e., rough drafts. It also incorporates peer evaluations into grades. This is expected to discourage students from free riding. Students were asked to estimate the number of students on their team that free rode for at least one major report. The number of free riders was not lower in Treatment A sections; in fact, it was slightly higher though not significantly (A/B: average = 0.542/0.523; standard deviation = 0.543/0.524; p=0.438). Treatment A teams were larger; this could be the cause of the slightly higher number of free riders. It also may be that the better accounting for free riders within the Treatment A grading scheme freed some students to free ride with less feelings of guilt. Students in both Treatments A and B-1 noted the presence of free riders during the focus groups: “It can be very annoying when team members do not pull their own weight” (Treatment A) and “Most of the class was all teamwork, and every lab and final project was done in a team. Some people didn’t work as hard as expected” (Treatment B-1). Treatment A does not appear to decrease student tendency to free ride. However, students in Treatment B emailed their professors almost twice as often to report or get help concerning problems with their laboratory team (A/B: average = 0.286/0.587; standard deviation = 0.691/2.05; p=0.027). Treatment A may reduce team conflict, perhaps by providing students with an effective structure for completing reports and evaluating peers. Also, Treatment A students may be more confident that grading will take free riders into proper account, because of the online peer evaluation tool and the submission of the two draft reports.

The focus groups provide insight concerning the characteristics of successful teams. Students noted that regular communication and collaboration outside of class were important in working well as a team. In addition, no student dominated team activities, and all members participated in both the experiments and completing the finished report. Students on well-functioning teams understood that, if they all cooperated, there was less work for each student to complete. The teams that reported a lack of cooperation found it more difficult to complete assignments.

Treatment A includes a laboratory leadership role. Each student is required to take on that role at least once during the semester. This forces students to take on more responsibility; it also prevents a single student from dominating over multiple lab sessions. Students were asked how often they assumed the leadership role (Figure 1). A Chi-Squared Goodness of Fit Test of the frequencies (shown in Figure 1 as percentages) indicates that the Treatments influence how often students' take on the leadership role ($p=0.000$). To calculate the Chi-Squared statistic, the top three categories were collapsed into a single "≥3" category, to ensure at least five observations per group. Over 50 % of Treatment B students never led a lab. Surprisingly, almost 25 % of Treatment A students also never led, indicating that this requirement should be emphasized more in the future. This was reflected in one of the focus groups for Treatment A in which a student noted: "We were not as successful at sticking to just our roles; we were trying to fill in too much and do other parts instead of our assigned part." Treatment B students were also more likely to lead 3 or more labs, suggesting that some students dominated their teams. Students in the Treatment B-1 focus group indicated that assigning roles during lab tended to happen organically. One group stated: "Leadership was evenly distributed, and a single person only took charge when it was necessary. Decisions were determined through a more democratic system."

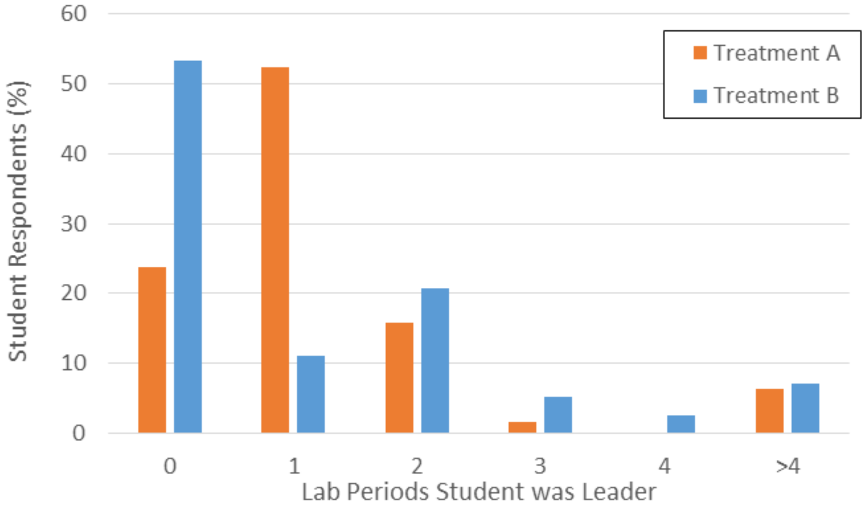

Figure 1: Laboratory Session Leadership

If Treatment A is an effective method of teaching team skills it is expected to lead to better lab reports and a better student experience. This was not the case from the student perspective. Students were asked: "What OVERALL GRADE does your laboratory team deserve on its Major reports in FEC I?" (Figure 2). Students in Treatment A did not assign significantly different letter grades from Treatment B students (Chi-Squared $p=0.481$). To calculate the Chi-Squared statistic, the bottom seven categories were collapsed into a single "≤B" category, to ensure at least five observations per group. It may be that Treatment A does not result in lab reports of different quality, at least from the student's perspective. Alternatively, Treatment A professors may have had higher expectations or standards, quite possible given their active participation in this study. This may have led to lower grades which could have effected students' perception of the quality of their reports. In future work, the assessment of lab reports by external evaluators should be used.

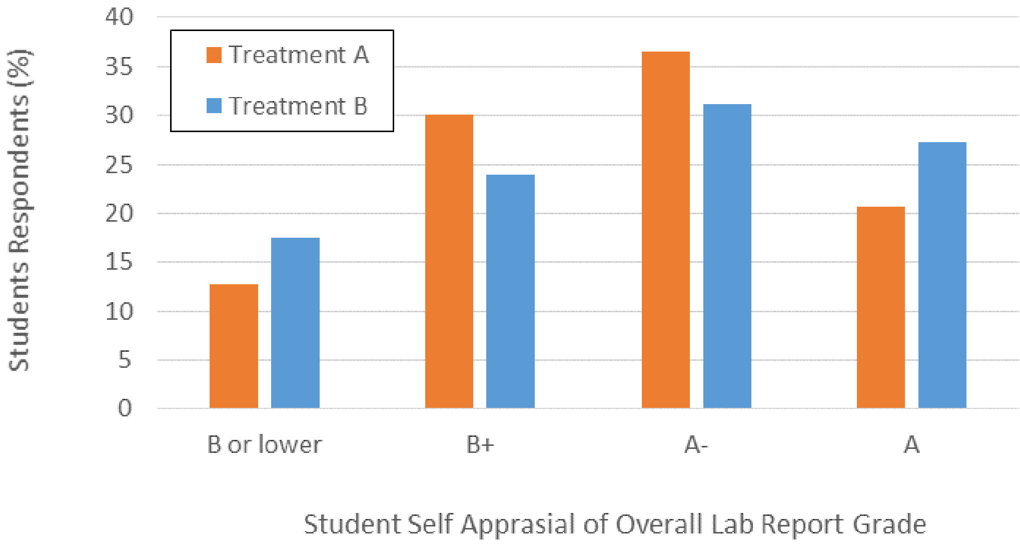

Figure 2: Overall Lab Report Grade

Students' self-appraisal of their teaming experience is given in Figure 3. Treatment A students reported higher percentages of OK, Good, and Wonderful assessments; however, a Chi-Squared Goodness of Fit Test of the frequencies indicates that the two treatments do not influence students' self-appraisal of their team experience (p=0.678).

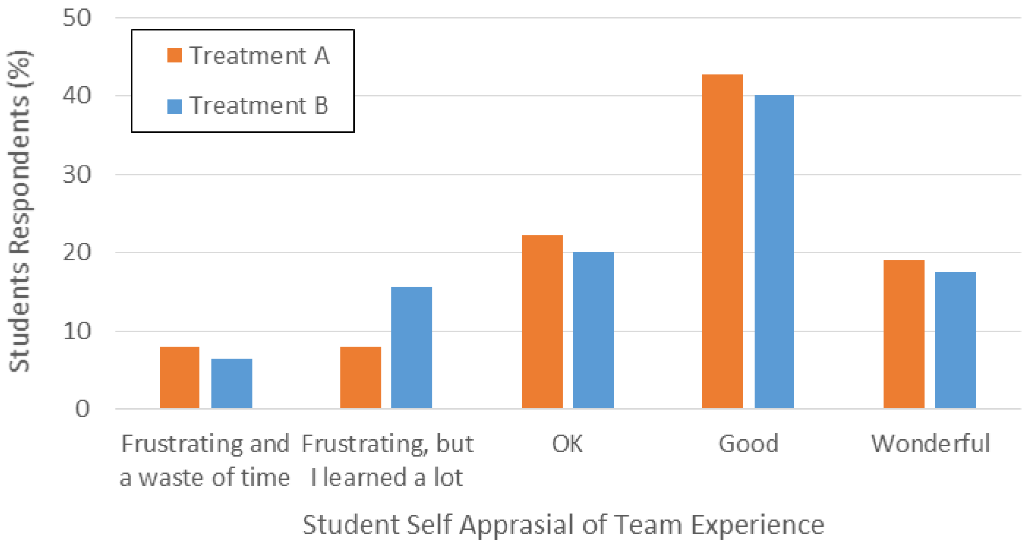

Figure 3: Student Appraisal of Experience with Teams in the Introduction to Engineering course

The analyses were repeated comparing only students in professors Morgan and Mallouk's Treatment A and B-1 sections. Sixty-six percent of the students in the 4 sections responded to the survey. There was no significant difference in student effort between the treatments (p=0.157). The major feature of the B-1 sections was the use of team contracts. Students completed peer evaluations on paper rather than on-line. Roles were suggested, but not described. Role rotation was not required. B-1 represents an alternative state-of-the-art team framework.

Many of the results were similar to the comparison using all sixteen sections (Table 5). Treatment A students wrote more different types of report sections. It also led to better leadership outcomes, e.g., 73 % of Treatment A students led at least one laboratory, compared to just under half of Treatment B-1 students.

Some major differences were observed. Treatment B-1 students reported higher teaming abilities at the end of the semester (p=0.100); however, they also reported higher ability at the start of the semester (p=0.040). Treatment B-1 students emailed their professors LESS often to report or get help concerning problems with their laboratory team, but the difference was not significant (p=0.286). The average number of laboratory reports before teams began to perform was slightly lower for Treatment B students (p=0.055). This suggests that team contracts may be more effective than pre-defined roles at reducing internal conflict, and team performance.

The most telling differences in the student focus group results were in the responses to the question regarding leadership roles. Students in Treatment A were better able to articulate a time they took on a leadership role in their team. For teams in one Treatment B-1 section, students ended up taking on leadership roles when the experiments dealt mostly with their engineering discipline, since this is an interdisciplinary class with experiments based on each engineering field of study. Teams in Treatment A also reported having an easier time working together, since they had assigned roles. More incidents of miscommunication within the teams were reported in Treatment B-1, with students needing to meet more in person to organize the work distribution within the team. The teams in Treatment B-1 who failed to meet in person reported difficulties in preparing and editing the lab reports.

Student responses to other questions asked of the focus groups brought to light similarities between treatment groups A and B-1. This information could reflect issues that face many student teams and could be used to help design future interventions in team design/management. For example, students in both treatment groups indicated that one of their major challenges was finding time to meet in person with their teams. For example, a student group in Treatment A noted: "The unsuccessful part of group work was the communication and our schedules, which were sometimes conflicting," A group in Treatment B had almost the identical comment: "We were unsuccessful when it came to figuring out when to meet and communication was a little difficult at times over text [messages]."

The faculty survey had a 100 % response rate and thus represents the faculty population for the course. Treatment B faculty met with an average of 1.2 individuals needing help or advice concerning problems with a laboratory team, while Treatment A faculty met with only 0.7. Similarly, Treatment B faculty met with an average of 0.9 teams needing help or advice concerning problems with a laboratory team, while Treatment A faculty met with only 0.7. On the other hand, Treatment A faculty remembered 2.3 emails from students seeking help or advice concerning problems with a laboratory team, versus only 0.9 for Treatment B faculty. Similarly, Treatment A faculty indicated that on average 2 of their laboratory teams had at least one significant conflict over the semester, versus only 1.1 for Treatment B faculty. It may be that the Treatment A faculty were more attuned to team performance, given their active participation in this study. Finally, Treatment A faculty observed an average of 2.7 reports before their teams began performing, versus 2.4 reports for Treatment B faculty. This contrasts sharply with the student reported averages of 1.3 and 2, respectively. Again, it may be that the Treatment A faculty had higher expectations or standards, quite possible given their active participation in this study. External evaluation of student reports should be used to assess this in future research.

Conclusions

A framework for managing and guiding student teams was developed, described, and compared to less structured, but commonly used, methods. The framework (Treatment A) was used in three sections of a 16 section first-year engineering course and involved guiding students to take on rotating roles during laboratory projects throughout the semester. Three versions of each report were submitted--rough draft, draft, and final--to make it easier to identify free-rider behavior during the report writing process. After each team assignment, students completed peer evaluations that were used to adjust final course grades.

When compared to all 13 Treatment B sections the Treatment A framework resulted in improvements in students' self-appraisal of their teaming abilities at the end of the semester, students writing more varied sections of laboratory reports, student teams more quickly entering the "performing" stage of the team adjustment phases, and more students taking on a leadership role at least once during the semester compared to the Treatment B framework. The Treatment A framework produced no reduction in free riders or increase in laboratory report quality, at least as observed or evaluated by students. While the submission of two draft reports does not appear to have significantly reduced free riding, in combination with online peer evaluation it may have reduced team conflict. Treatment A is recommended as a team framework.

Some of the differences observed between the three Treatment A sections and all thirteen Treatment B sections disappeared when only comparing Professors Morgan and Mallouk's A and B-1 sections. This might indicate that some of the differences observed in all sixteen sections may be teacher effects. Alternatively, the techniques used in the B-1 sections (primarily team contracts, role description, and paper peer evaluation) might be as or even more effective than Treatment A. Treatments A and B-1 are complimentary. Combining them is recommended as a team framework.

The results from this research can be used to encourage faculty members to provide guidance to their student teams on ways to manage teamwork. Providing specific roles for each team member to rotate through gives students a basis for organizing their teams. It also makes them practice the typical roles employed by members of successful teams and gain experience writing a wide range of laboratory report sections. Enhanced team organization may also ease student communication and reduce team conflict, which helps team productivity overall, and provides students a strong foundation for working-world teamwork. Finally, requiring students to turn in specific drafts and having students evaluate each other may reduce team conflict and increase student confidence and comfort regarding team grading.

The results also brought to light some common issues that student teams face that warrant further exploration. These issues include struggling to communicate well and finding times to meet in person. While the advent of programs such as Dropbox and Google Drive have made online collaboration easier, they do not necessarily serve as total replacements for face-to-face meetings. Finally, to determine if the quality of laboratory reports is affected by the treatment described here, external uniform evaluation should be employed in future research.

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