Pre-defined roles and team performance for first year students

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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 planner, meeting scheduler or facilitator, task assigner, mediator, 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 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 introduction to 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 a first-year introduction to 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

New teams may go through an initial period of adjustment. According to Tuckman new groups go through four phases: Forming, Storming, Norming, and Performing.[1] During the Forming stage group members try to size up each other, find the limits of acceptable group behavior, and clarify the group task.[2] In the Storming stage 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 by Shuman et al., Dym et al., Felder and Brent, Smith et al., and Barrick et al. have provided a summary of how to instruct students using collaborative projects.[3,4,5,6,7,8] 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 conflict. This creates a missed opportunity on the instructor's part of being able 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. This is to prepare students to engineer 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.[8]

Smith et al. emphasizes that there are five key elements in creating successful collaborative learning experiences for the students.[7] 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, and Smith suggests 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 are inherently gaining teamwork skills. It is also essential that the group processes the results of their collaborative work, and emphasizes a 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.[4] There are the inherent difficulties of students working on a team that is composed of weaker students, but a team of students that have higher academic abilities can also be detrimental. According to Felder, a team of high achieving students tend to 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.[5] 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.[6] At the same time, it is important that teams develop a strategy to compensate for the differences in personalities as they are forming the team. This strategy will be essential in their ability to effectively work together.

Finally, it is also crucial that the complexity of the collaborative assignment given to the students is considered when utilizing 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.[3] Time limits, and deadlines that encourage the assignment to be completed through collaboration, are essential when designing 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 Lei 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.[9] Prince et al. note the use of assigned roles in teams, but do not specify which roles they used in freshman courses.[10]

With these theories and observations in mind, we endeavor to 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[6], while this study 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 the 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 has five engineering majors: Biomedical, Chemical, Civil & Environmental, Electrical & Computer, and Mechanical. 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 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. The primary author used Treatment A. Professors Morgan and Mallouk taught two sections each, using Treatment A in one and Treatment B-1 in the other. The remaining nine professors used various treatments (B-2) in eleven sections. The primary author is a professor with over 20 years' experience teaching freshman through graduate level courses. Professors Morgan and Mallouk are both instructors in their second year of teaching primarily first and second year courses. The remaining professors

include professors, instructors, temporary faculty, adjuncts, and teaching fellows (graduate students) with a wide range of experience.

All sections of the Introduction to Engineering course use the same online Ebook, customized for the course.[11] It includes 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).

Treatment A

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.[12] The LCI uses four styles to describe how an individual prefers to learn: Sequential, Precise, Technical, and Confluent.[13] Teams are selected to distribute learning styles as evenly as possible. Each team of five students has zero, two or three female members, to avoid isolating a single female on a team of five, except in the case where only one female is enrolled in a section. Students are assigned to teams so that majors are distributed as widely as possible; ideally, each team has five 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)
    - Section writer (different ones for each report)
    - Compiler
    - 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, two students physically conducting the lab, and two 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:

- Rough Draft – report consisting of raw sections as created by each section writer and combined by the compiler with section author name placed next to each section title;
- Draft – report after compiler has addressed grammatical and spelling errors, style issues, and missing information (compiler may also send sections back to original author); and

- Final – report after 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, 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 mean, 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 working in teams: 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.

Treatment B (B-1 and B-2)

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.[14] 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.[15] Peer evaluation results were used to modify laboratory assignment grades as described by Kaufman et al. 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 eleven Treatment B sections (B-2), professors used a variety of methods to form, manage, and evaluate teams, based on their past experiences. In four sections, students were allowed to form their own teams. In the other seven, 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.[16] 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 eleven 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.

Analysis

The Treatments are compared using: (1) a student survey; (2) a professor survey; and (3) focus groups conducted in Professors Morgan and Mallouk's four sections at the end of the semester. The student survey was conducted online and was completed by 217 of 366 students, 59 %. The

faculty survey was completed for all 16 sections, 100 %. 50 students from Professor X's sections (98%) and 37 students from Professor Y's sections (84%) attended the focus sections.

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

All Sections - Student Survey

A number of analyses were made by comparing the three Treatment A sections to all thirteen Treatment B sections (B-1 and B-2). Student quotes provided in this section are from the focus groups held in Professors Morgan and Mallouk's four sections.

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 zero team reports. There is no significant difference in the number of major reports worked on before college between students in Treatments A and B (A/B: mean=6.94/5.66; standard deviation=9.20/10.4; p=0.182).

Table 1: Number of times students worked in a team to create a significant laboratory report before college

Frequencies		**Statistics**	
Response	**Number Responses**	**Parameter**	**Value**
0	73	*Number of Responses*	*223*
1	23	*Minimum*	*0*
2	18	*Maximum*	*50*
3	17	*Average*	*6.0*
4	18	*Standard Deviation*	*10.1*
5	18		
6	2		
7	1		
8	3		
9	0		
10	18		
>10	32		

Students' self-appraisal of their ability to work in teams is given in Table 2. The student responses were converted to numerical values: "Very Poor" = 1; "Poor" = 2; "Average" = 3; "Good" = 4; and "Excellent" = 5 to estimate means and standard deviations and conduct statistical tests. The mean self-appraisal of teaming ability of all students increased significantly from the start to the end of semester, from 3.6 to 4.3 (p=0.000), indicating that both Treatments improve students' self-appraisal of teaming abilities. Treatment A students did not give themselves significantly higher appraisals at the start of the semester compared to Treatment B students (p=0.115), but did at the end (p=0.048). This indicates that something in those three sections strengthened student's self-appraisal of their teaming abilities, perhaps the Treatment A framework. This better self-appraisal occurred despite writing fewer reports (A/B: mean=4.1/4.3; standard deviation=1.1/2.7; p=0.078) and serving on larger teams (A/B: mean=4.68/4.00; standard deviation=0.222/0.547; p=0.000). Treatment A sections averaged 25.3 students, while Treatment B sections averaged 23.2.

Table 2: Student self-appraisal of ability to work in teams at the start and end of the semester.

Answer Options / Parameters	**Start of Semester**		**End of Semester**	
	A	**B**	**A**	**B**
Very Poor	0	1	0	0
Poor	1	8	1	3
Average	23	60	1	13
Good	34	72	36	88
Excellent	7	16	27	53
Total	*65*	*157*	*65*	*157*
Average	*3.7*	*3.6*	*4.4*	*4.2*
Standard Deviation	*0.67*	*0.77*	*0.60*	*0.67*
Z_o	*1.20*		*1.66*	
p-value	*0.115*		*0.048*	
Average	*3.6*		*4.3*	
Standard Deviation	*0.741*		*0.655*	
Z_o	*9.43*			
p-value	*0.000*			

Table 3 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 means and standard deviations and conduct statistical tests. The mean for students in Treatment A is not significantly higher (p=0.231) than Treatment B's mean. This indicates that the significantly higher end of semester ability (Table 2) is not due to a higher level of effort forced by Treatment A.

Table 3: Student self-appraisal of level of effort in laboratory-related team work in Introduction to Engineering course

Answer Options / Parameters	**A**	**B**
Very Weak	0	1
Weak	0	2
Average	11	33
Strong	36	76
Very Strong	18	45
Total	*65*	*157*
Average	*4.1*	*4.0*
Standard Deviation	*0.62*	*0.78*
Z_o	*0.735*	
p-value	*0.231*	

Students were asked how many different types of report sections they wrote over the course of the semester. The mean number of report sections is significantly higher for students in Treatment A (A/B: mean=6.82/5.63; standard deviation=2.34/2.75; p=0.001), even though Treatment B teams wrote slightly more reports. Furthermore, 42 % of Treatment B students wrote four or fewer different sections and only 35 % wrote seven or more. Contrast this to Treatment A students; only 16 % wrote four or fewer while 56 % wrote seven or more. This indicates that Treatment A compelled students to write different sections, which should help them with future report writing. Surprisingly, though it required students to edit other students' work, Treatment A students reported editing slightly fewer sections written by other students (the difference was not significant). Given that Treatment A students reviewed other students work after it had been compiled into an entire report, it is possible that students did not interpret this question as intended. They may not have recognized that editing the report was also editing sections.

Students were also asked to estimate the number of students on their team that were free riders for at least one major report. The number of free riders was not lower in Treatment A sections; in fact, it was slightly higher (not statistically significant, A/B: mean = 0.540/0.523; standard deviation = 0.543/0.524; p=0.438). Treatment A teams were larger; this could be the result of the slightly higher number of free riders. 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: mean = 0.286/0.587; standard deviation = 0.691/2.05; p=0.026). 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.

Treatment A defines a laboratory leadership role and requires each student to take on that role at least once during the semester. 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 two treatments influence students' self-appraisal of their team experience (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.

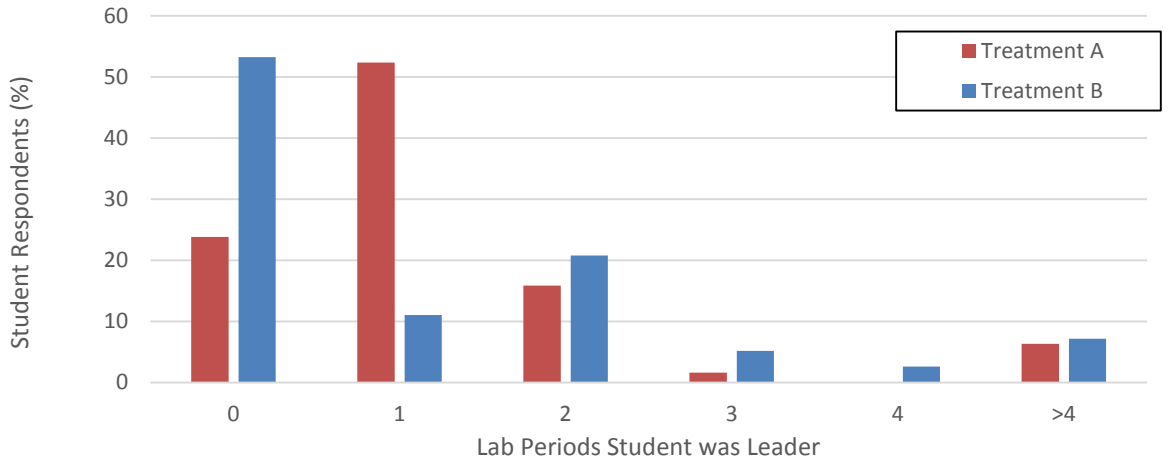

Figure 1: Laboratory Session Leadership

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 students 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."

Students in Treatment A did not assign a significantly higher mean grade to their team's major lab reports (A/B: mean = 90.6/90.2; standard deviation = 3.56/5.26; p=0.285). This indicates that Treatment A does not result in better lab reports, at least from the student's perspective. It is also possible that the Treatment A professors had higher expectations or standards, quite possible given their active participation in this study. This may have led to lower report grades which could have effected students' perception of the quality of their reports. In future work, the assessment of lab reports by external evaluators could be used.

Professors Morgan and Mallouk's Sections - Student Survey

The analyses presented so far were repeated comparing only students in professors Morgan and Mallouk's section, i.e., Treatment A versus B-1. Sixty-six % of the students in the four sections responded to the survey. Many of the results were similar to the comparison using all sixteen

sections. When students rated their teamwork abilities at the start of the semester, the Treatment B-1 student mean was significantly higher (p=0.038). By the end of the semester it was not (p=0.002), indicating that Treatment A raised students' self-appraisals relative to Treatment B-1. Treatment A resulted in students writing more types of report sections. Fifty-three percent of Treatment B-1 students never led a laboratory, compared to only twenty-seven percent of Treatment A students. The number of major reports was the same for the two Treatments, set purposefully by Professors Morgan and Mallouk.

Different outcomes were also observed. Team size was not significantly different. Students in Treatment B-1 reported expending more effort on laboratory-related team work (P=0.076). Treatment A students reported more free riders, but the difference was not significant (p=0.125). Treatment A students emailed their professors 1.4 times as often to report or get help concerning problems with their laboratory team, but the difference was not significant (p=0.286). Neither Treatment is expected to produce or encourage free riders. It is possible that the Treatment A sections simply had more students prone to free riding, and this led to more emails.

The statistical comparisons are summarized in Table 4. Comparisons of Treatments A and B use all sections. Comparisons of Treatments A and B-1 are for the four sections of Professors Morgan and Mallouk.

Table 4: Summary of statistical comparisons

Comparison	**Result**
Major reports before college	No difference between Treatments A and B
Team Size	Treatment A significantly higher than B
	No difference between Treatments A and B-1
Number of major reports	No difference between Treatments A and B (or B-1)
Change in teaming abilities	Higher at end of semester (All students)
Teaming abilities, start of semester	Treatment A and B not significantly different
	Treatment B-1 significantly higher than A
Teaming abilities, end of semester	Treatment A significantly higher than B
	No difference between Treatments A and B-1
Effort expended in laboratory-related team work	No difference between Treatments A and B
	Treatment B-1 significantly higher than A
Number of different types of report sections written over semester	Treatment A significantly higher than B (or B-1)
Number of free riders on team	No difference between Treatments A and B (or B-1)
Number of emails to professor to report or get help concerning problems with team	Treatment B significantly higher than A
	No difference between Treatments A and B
Number of times led team during laboratory period	Significant difference between Treatment A and B (or B-1). Treatment A students less likely to have never led, or led more than 2 times.
Team grade (self-appraisal)	No difference between Treatments A and B (or B-1)

Faculty Survey – All Sections

No statistical results are realized from the survey of twelve faculty, as the sample size is small. 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.

Focus Group Results

The most telling differences in the 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 Professor Y's Treatment B-1section, 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]."

Conclusions

A framework for managing and guiding student teams was developed, described, and compared to less structured, commonly used, methods. The framework (Treatment A) was used in 3 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.

The results of a student survey, faculty survey, and multiple focus groups indicated that 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, 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, 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 reduce team conflict.

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 indicates that some of the differences observed with all sixteen sections may be teacher effects. Alternatively, the techniques used in the B-1 sections (handout, paper peer evaluation, and contract) could be as effective as those used in the A sections.

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 teams with specific roles that each member is expected to rotate through gives students a basis for organizing their teams, but also gives them practice exploring a variety of roles and writing different laboratory report sections that they might not otherwise take on. This 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 projects. 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 like Dropbox and Google Docs have made collaboration online 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 must be employed in future research.

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