(Not) Feeling Lonely in a Team: implementation and assessment of equitable team formation practices (Work in Progress).

Arnold Deffo, California Polytechnic State University, San Luis Obispo

Arnold Deffo is an Assistant Professor in the Aerospace Engineering Department at Cal Poly, San Luis Obispo. He comes from the California Institute of Technology where he completed his M.S. and Ph.D. in Aeronautics. Prior to that, he was at Wichita State University where he obtained bachelor degrees in Aerospace Engineering and Mathematics. He is passionate about diversity, inclusivity, and mentoring, especially when it comes to helping students from under-represented minorities succeed in STEM-related fields.

(Not) Feeling Lonely in a Team: implementation and assessment of equitable team formation practices (Work in Progress)

Abstract: Modern engineering practice involves teamwork, collaboration, and communication, skills graduates should possess for long-term success in the field. However, teamwork in engineering curricula is often fraught with a range of challenges that extend beyond the content of a given course or project. In engineering education, researchers have been interested in mechanisms for forming teams in ways that improve performance and mitigate social and interpersonal challenges associated with teamwork. In this work in progress, we explore the efficacy of a scheme for forming engineering project teams. Specifically, we compare two different sections of a course in aerospace engineering. In one section, teams are formed intentionally by the instructor according to existing best practices regarding equitable team formation. For example, we form groups while ensuring equitable representation of marginalized identities (e.g., making sure no woman is the only such person in a team). In the other section, students are allowed to self-select into their own teams. Quantitative data are collected via a teamwork satisfaction instrument as well as course GPA and other performance indicators. We use T-tests to compare experiences both across and within class sections via pre/post analysis of survey data. Because students in self-formed groups typically tend to do so based on familiarity with classmates, we predict a greater level of satisfaction at the start compared to their assigned counterparts. Findings suggest that students in assigned teams (as done in the present study) exhibit improved levels of team satisfaction after completion of the group work. Moreover, while students in the self-selected group report higher levels of initial satisfaction, those levels decrease over time along with other performance indicators. Based on these findings, we suggest that forming teams according to the methods outlined in the present work provides positive experiences for students and potentially more fully prepares them for success beyond the classroom. Importantly, because assigning teams might be perceived as disempowering to students—at least initially—engineering educators should work to be transparent in their team formation practices and explain to students the rationale for such approaches.

1. Introduction

As engineering students graduate and enter the workforce, they are expected to possess numerous skills necessary for long-term success in the field. Chief among them is the ability to work collaboratively in teams [1]. This is because modern engineering practice requires proper collaboration and communication. It is therefore not surprising that exposing students to team-related work is at the core of many engineering upper-division courses. However, despite such efforts, it is also well known that when not carefully implemented, team activities inside the classroom often lead to students' dissatisfaction with the experience [2]. Indeed, teamwork in engineering curricula is often fraught with a range of challenges that extend beyond the content of a given course or project. In engineering education, researchers have been interested in mechanisms for forming teams in ways that improve performance and mitigate social and interpersonal challenges associated with teamwork [3-7]. Given its widespread use, the tools provided by the Comprehensive

Assessment of Team Member Effectiveness (CATME) [7] have come to be regarded as a model for forming effective engineering teams. However, it should be noted that using CATME either by an instructor or a student requires the payment of a service fee which many students may not find affordable. As a result, in this work in progress, we build on the work of Potosky and Duck [8] to explore the efficacy of a scheme for forming engineering project teams. Specifically, we compare two different sections of a course in aerospace engineering. In one section, students are allowed to self-select into their own teams while in the other, teams are formed intentionally by the instructor following the method described in this paper. For example, whenever possible, we form groups while ensuring equitable representation of marginalized identities (e.g., making sure no woman is the only such person in a team). Quantitative data are collected via a teamwork satisfaction instrument as well as course GPA and other performance indicators. In an effort to evaluate the efficacy of the proposed method, we use T-tests to compare experiences both across and within class sections via pre/post analysis of survey data. Because students in self-formed groups typically tend to do so based on familiarity with classmates, we anticipate a greater level of satisfaction at the start of the group project compared to their assigned counterparts. However, we predict that this difference becomes insignificant at the end of the group project.

This paper is organized as follows: Part 2 revisits and details the hypotheses we make to test the effectiveness of the proposed method. In Part 3, we describe the group forming scheme employed in the present study and emphasize its attempt to create equitable teams. The results of the study are presented in Part 4, followed by a discussion in Part 5. Part 6 summarizes and concludes the paper.

2. Hypothesis

This work explores the efficacy of a scheme for forming engineering teams as part of a term-long group project by comparing two different sections of a course in aerospace engineering. In one section, which we call *Section 2*, teams are formed intentionally by the instructor according to a modified implementation of the method proposed by Potosky and Duck [8]. In the control group, call it *Section 1*, students are allowed to roughly self-select into their own teams. Inevitably, this often leads to students electing to work with classmates with whom they are already familiar. In light of this, the goal of the present study is to expose students to a diversity of backgrounds by pairing them with students they may not elect to work with otherwise and to compare the levels of satisfaction of students in each section with regard to their team assignments. With regard to the above goals, we make the following two hypotheses:

1. Forming groups using the method described in this paper has no adverse effect on individual student performance. In other words, we anticipate that the average group project performance (or letter grade) of students in *Section 2* will be no worse than that of students in *Section 1*.
2. While students in *Section 2* may initially show lower levels of satisfaction with their team assignment compared to their peers in *Section 1*, we predict that they will show

improved levels of satisfaction and report better team dynamics than their peers in *Section 1* after completion of the group project.

In the following, we expand on the methods employed to carry out the study and provide results and corresponding interpretation.

3. Methods

The comparative nature of this study led to the consideration of two sections of a course in aerospace engineering. In the first section, which we call *Section 1*, students are allowed to self-select into groups. This section also serves as the control group for the study. In the other section, *Section 2*, students are intentionally assigned to teams following the group forming scheme described below.

a. Group Forming Scheme

The group forming scheme employed in the present study is adopted from the work of Denise Potosky and Janet Duck [8]. Unfortunately, their work does not explicitly consider the diversity of team members other than as it relates to their potential contribution to the group work. As a result, we supplement the approach described in [8] with existing best practices regarding equitable team formation [6, 9, 10] to offer a modified version which considers various aspects of individual team members (race, gender, potential contribution to teamwork, personality, etc.). We provide below the four key steps comprising the modified group forming scheme as it is implemented in the present study.

I. *Establishing the Criteria*

As described in Potosky and Duck [8], this step consists, after reviewing the assigned group project, of explicitly stating the relevant outcome interdependence and task interdependence. As part of outcome interdependence, students generate a list of their expectations for successful completion of the team assignment. Also included here is a grading rubric as well as whether every student in the same group gets the same grade. In task interdependence, students, with the guidance of the instructor, generate a list of critical roles as well specific skillsets necessary for successful completion of the group project.

For projects spanning an entire academic term as is the case in this study, we recommend this step be carried out as soon as possible, perhaps on the first day of class. Regardless of the day this step is implemented, call it *Day 1*.

Note: Though the group forming scheme described here is implemented in *Section 2*, the first step above (*Establishing the Criteria*) is also implemented in the control group, i.e. *Section 1*.

II. *List the Criteria in an Online Survey*

Following the class activity on *Day 1*, and using the list generated under task interdependence, the instructor creates a survey asking each student to self-identify their potential contribution to the project group, as well as their gender, race, and other aspects of their personality (e.g. collectivism vs. individualism,

source(s) of motivation, view on engineering and social justice, etc.). In keeping with the spirit of Potosky and Duck [8], this survey should give students the option to select multiple answers. It is also important that a sort of "catch-all" answer be included so as to bring students to choose at least one answer. In this study, we use the survey of *Appendix A* to that effect. For reasons given below, students should complete the online survey before the second day of class, call it *Day 2*.

III. Facilitate Assignment into Teams

After students complete the survey, and before class on *Day 2*, the instructor proceeds to form groups based on a potential member's strength(s) and other diversity components—as highlighted in their response to the survey. Specifically, it is important that, whenever possible, the instructor ensures that (i) the skillsets in a group are complementary—for successful completion of the project, and (ii) there are at least two underrepresented minority students in each group—to provide an immediate support system to those students and mitigate the risk of stereotype threat [5, 11].

During class on *Day 2*, the instructor announces the different groups and, in an effort to establish group potency, the implementation proceeds as in Potosky and Duck [8] by allowing students to interact with their newly assigned teammates and discuss their potential contribution to the team.

IV. Process the Activity with Students

Following the group assignments, the instructor proceeds to process the activity with the students. Among other things, this includes reviewing information from the group and team forming literature that addresses the strengths and advantages of diverse groups (in terms of skills, gender, race, socio-economic status, etc.) compared to their homogeneous counterparts.

b. Pre-project Survey

Following formation of the teams in both sections, the instructor creates a pre-project survey to measure the level of student satisfaction with their chosen teams (for those in *Section 1*) or assigned teams (for those in *Section 2*). Specifically, the questions making up the pre-project survey should be chosen so as to address the metrics under consideration (e.g. satisfaction with team assignment, forecasting, ease of working with teammates, etc.). In an effort to measure the immediate sentiment of students with regard to their teams, this survey should be available on the same day students form or are informed of their group project teams. For the present study, the pre-project survey consists of the following questions:

Q1. On a scale of 1 (very dissatisfied) to 10 (very satisfied), are satisfied are you with your team assignment?

Q2. On a scale of 1 (very unlikely) to 10 (very likely), how easily do you foresee yourself working well with your teammates as part of this project?

Q3. Please provide additional thoughts or comments here.

c. Post-project Survey

Upon completion of the group project, students are asked to take a post-project survey which revisits the questions asked previously as part of the pre-project survey. However, the post-project now asks students to provide answers based on their experiences as part of the just-completed term-long project. For reasons already mentioned above, it is important that, here as well, the survey be available to students immediately after completion of the group project. Building on the questions from the pre-project survey, the post-project survey in this study consists of the following questions:

Q1. Thinking back on your experience as part of this group project, on a scale of 1 (very dissatisfied) to 10 (very satisfied), how satisfied are you with your original team assignment?

Q2. On a scale of 1 (very unlikely) to 10 (very likely), how easy was it to work well with your teammates as part of this project?

Q3. Please provide additional thoughts or comments here.

4. Results

Before presenting the results of the pre- and post-project surveys, it is important to shed some light on the data from the survey of *Appendix A* as this one guided the formation of teams in *Section 2*—see Tables 1 - 4.

Which of the following do you value more?	
Collectivism	*Individualism*
38	16
70%	30%

Table 1: Response distribution to question 2 of Appendix A.

Gender Identity		
Female	*Male*	*PNTD*
14	39	1
26%	72%	2%

Table 2: Response distribution to question 3 of Appendix A.

Note: PNTD stands for "Prefer not to disclose".

Role of Engineer with regard to social justice				
None	*Limited*	*Somewhat important*	*Important*	*Very important*
7	7	13	16	11
13%	13%	24%	30%	20%

Table 3: Response distribution to question 5 of Appendix A.

Racial identity							
Asian	*Multiracial*	*Black*	*Hawaiian*	*Latinx*	*Native*	*White*	*PNTD*
4	1	1	1	4	1	41	1
7%	2%	2%	2%	7%	2%	76%	2%

Table 4: Response distribution to question 7 of Appendix A.

With regard to the results of the pre- and post-project surveys, we first provide a comparison of the pre-project survey results for both sections, followed by a comparison of the post-project survey results. These results are later repeated in a different form by comparing the students' responses within sections directly. As a reminder, *Section 1* serves as the control group while our group forming scheme is implemented in *Section 2*.

a. Pre-Project Results

Below are the results of the pre-project survey

- **Q1:** On a scale of 1 (very dissatisfied) to 10 (very satisfied), how satisfied are you with your team assignment?

	Enrollment	Responses	Median	Average	Std Dev
Section 1	52	44	8.5	8.57	1.44
Section 2	62	48	8	7.94	1.59

Table 5: Q1 Statistics in Pre-project Survey (T-test: t = 1.99, nu = 89, p<0.05)

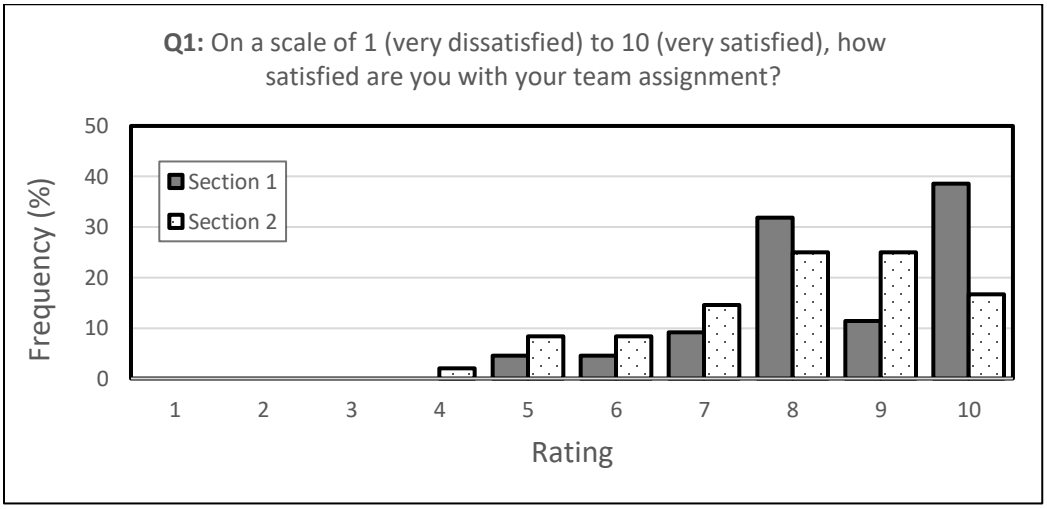

Figure 1: Q1 Response Distribution in Pre-project Survey

- **Q2:** On a scale of 1 (very unlikely) to 10 (very likely), how easily do you foresee yourself working well with your teammates as part of this project?

	Enrollment	Responses	Median	Average	Std Dev
Section 1	52	44	9	8.66	1.12
Section 2	62	48	8	8.27	1.30

Table 6: Q2 Statistics in Pre-project Survey (T-test: t = 1.55, nu = 89, p>0.05)

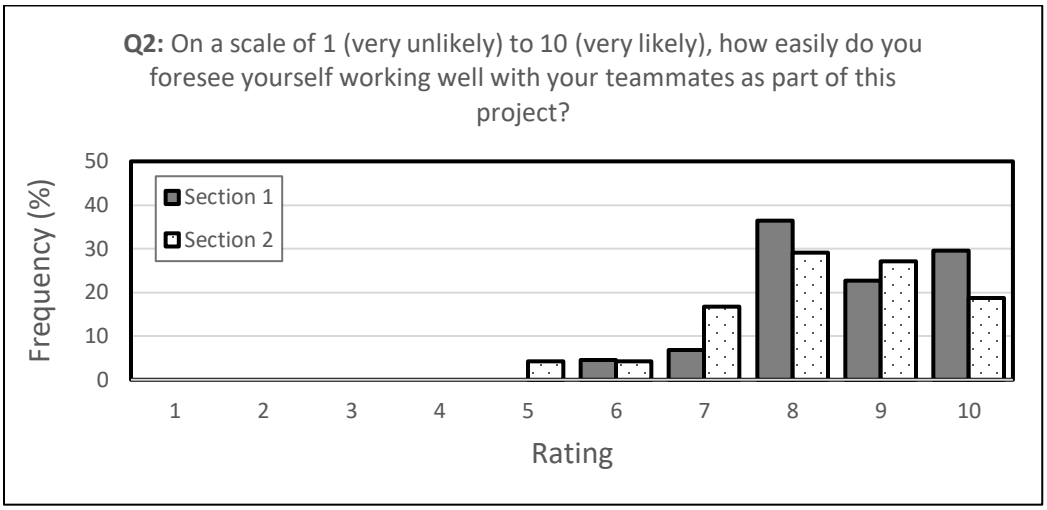

Figure 2: Q2 Response Distribution in Pre-project Survey

b. Post-Project Results

We summarize below the results of the post-project survey.

- **Q1**: Thinking back on your experience as part of this group project, on a scale of 1 (very dissatisfied) to 10 (very satisfied), how satisfied are you with your original team assignment?

	Enrollment	Responses	Median	Average	Std Dev
Section 1	52	22	9	8.59	1.65
Section 2	62	28	8.5	7.96	2.13

Table 7: Q1 Statistics in Post-project Survey (T-test: t = 1.18, nu = 48, p>0.05)

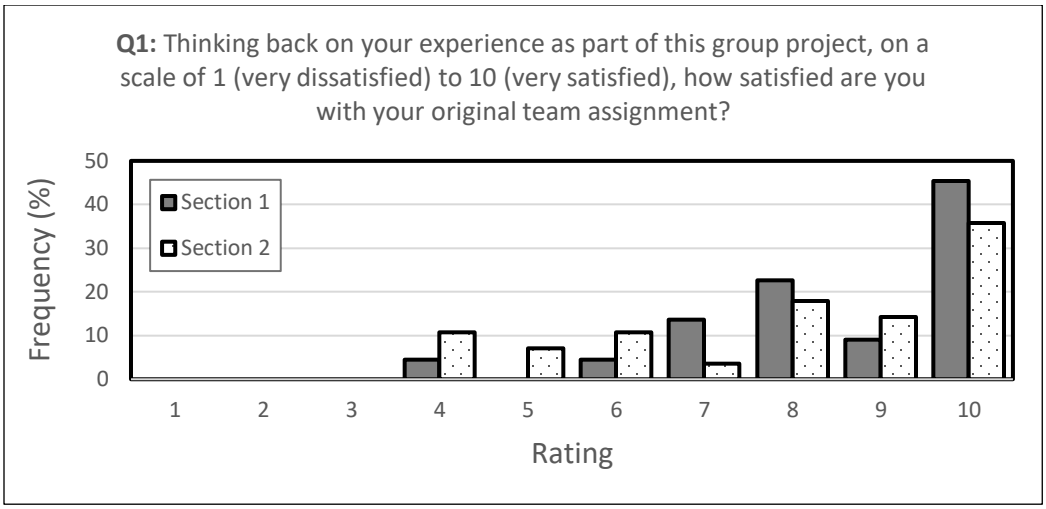

Figure 3: Q1 Response Distribution in Post-project Survey

- **Q2:** On a scale of 1 (very unlikely) to 10 (very likely), how easy was it to work well with your teammates as part of this project?

	Enrollment	Responses	Median	Average	Std Dev
Section 1	52	22	8	8.09	1.77
Section 2	62	28	8	7.93	1.94

Table 8: Q2 Statistics in Post-project Survey (T-test: t = 0.30, nu = 46, p>0.05)

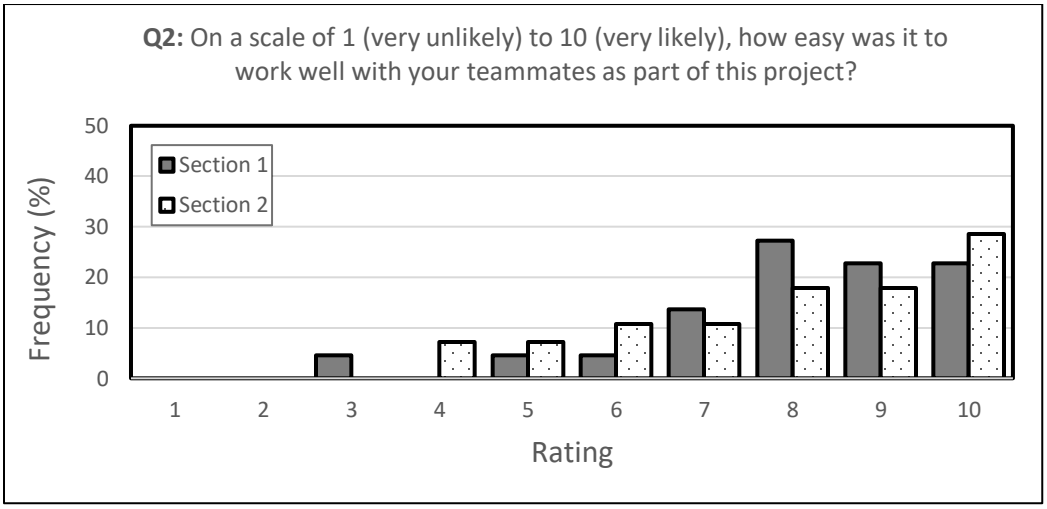

Figure 4: Q2 Response Distribution in Post-project Survey

c. *Section 1* Results

In order to better understand the effect of the group forming scheme described in the study, we present below the survey results within *Section 1*, comparing the pre-project responses to post-project responses. Again, the questions as asked to the students are listed in Parts 3(b) and 3(c) respectively. Here, we simply list a synthesized version that encompasses both the pre- and post-project questions.

- **Q1:** (Thinking back on your experience as part of this group project) on a scale of 1 (very dissatisfied) to 10 (very satisfied), how satisfied are you with your (original) team assignment?

	Enrollment	Responses	Median	Average	Std Dev
Pre-project	52	44	8.5	8.57	1.44
Post-project	52	22	9	8.59	1.65

Table 9: Q1 Statistics of Pre- and Post-project Survey Results in Section 1 (T-test: t = 0.05, nu = 37, p>0.05)

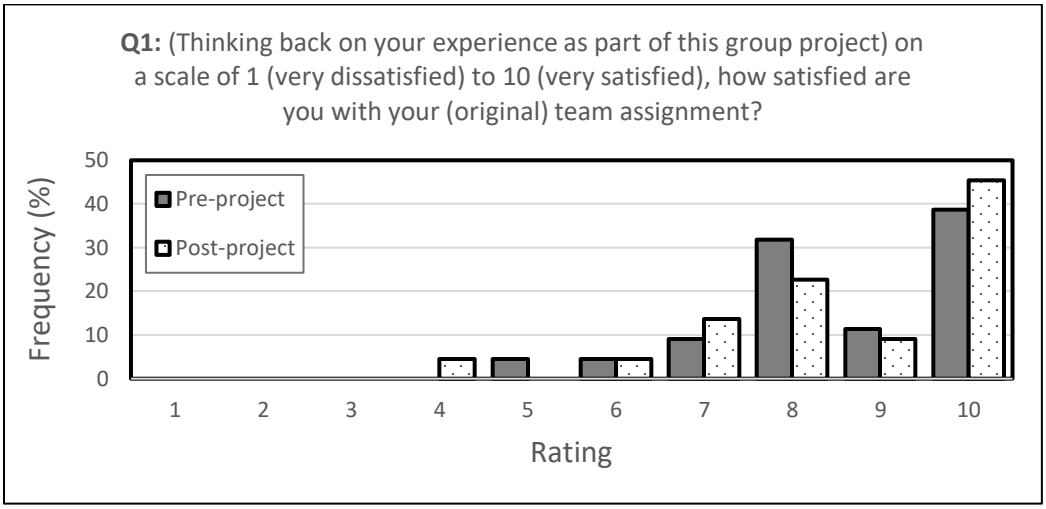

Figure 5: Q1 Response Distribution in Pre- and Post-project Surveys in Section 1

- **Q2:** On a scale of 1 (very unlikely) to 10 (very likely), how easy was it/do you foresee yourself working well with your teammates as part of this project?

	Enrollment	Responses	Median	Average	Std Dev
Pre-project	52	44	9	8.66	1.12
Post-project	52	22	8	8.09	1.77

Table 7: Q2 Statistics of Pre- and Post-project Survey Results in Section 1 (T-test: t = 1.38, nu = 29, p<0.05)

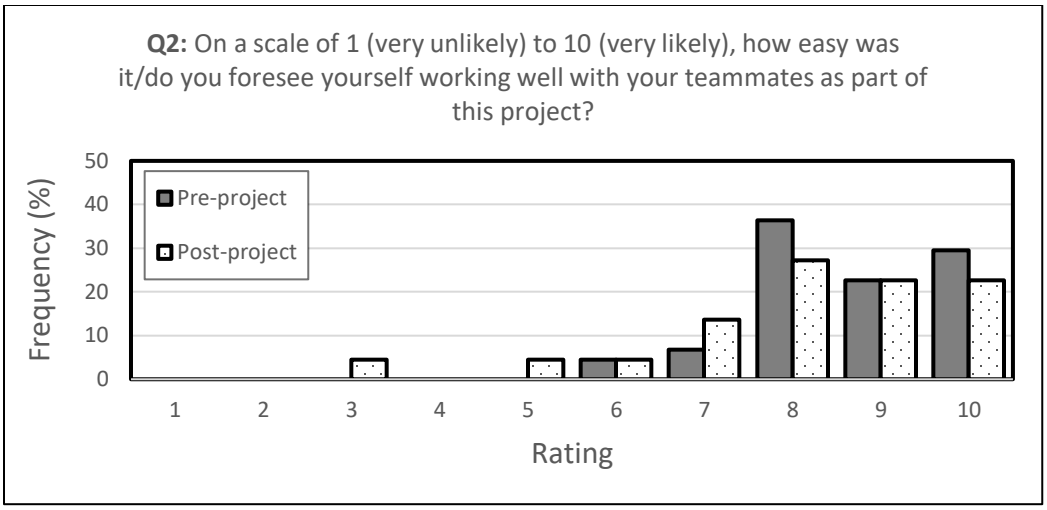

Figure 6: Q2 Response Distribution in Pre- and Post-project Surveys in Section 1

d. *Section 2* Results

Proceeding similarly to above, we present below the survey results within Section 2, again comparing the pre- to post-project responses.

- **Q1:** (Thinking back on your experience as part of this group project) on a scale of 1 (very dissatisfied) to 10 (very satisfied), how satisfied are you with your (original) team assignment?

	Enrollment	Responses	Median	Average	Std Dev
Pre-project	62	48	8	7.94	1.59
Post-project	62	28	8.5	7.96	2.13

Table 11: Q1 Statistics of Pre- and Post-project Survey Results in Section 2 (T-test: t = 0.04, nu = 44, p>0.05)

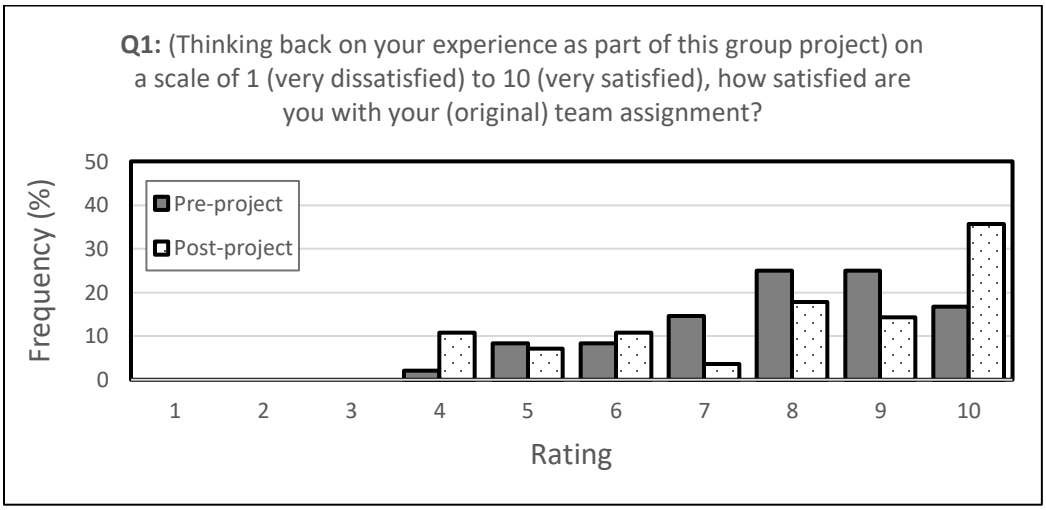

Figure 7: Q1 Response Distribution in Pre- and Post-project Surveys in Section 2

- **Q2:** On a scale of 1 (very unlikely) to 10 (very likely), how easy was it/do you foresee yourself working well with your teammates as part of this project?

	Enrollment	Responses	Median	Average	Std Dev
Pre-project	62	48	8	8.27	1.30
Post-project	62	28	8	7.93	1.94

Table 12: Q2 Statistics of Pre- and Post-project Survey Results in Section 2(T-test: t = 0.83, nu = 41, p>0.05)

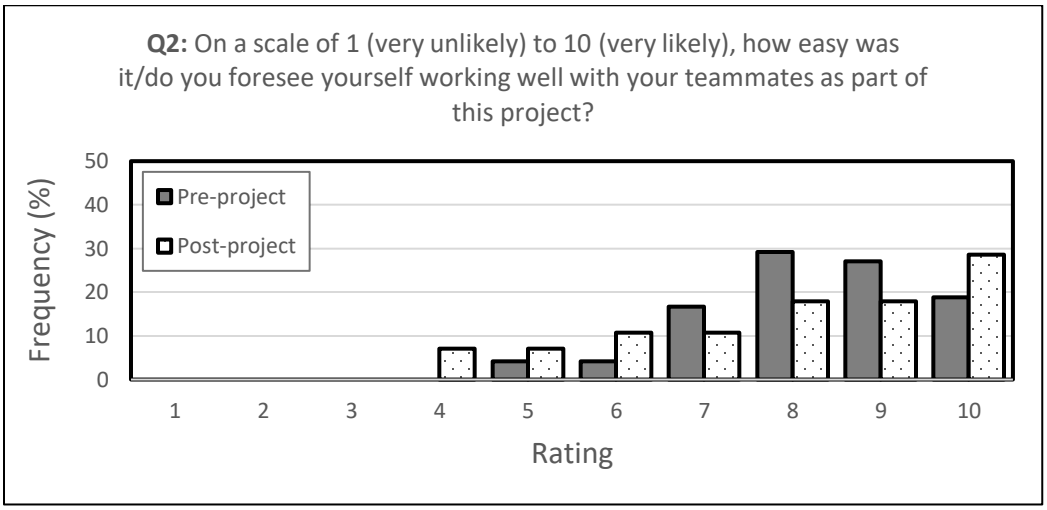

Figure 8: Q2 Response Distribution in Pre- and Post-project Surveys in Section 2

e. Average Student Performance

Lastly, we compare in Table 13 students' performances in both sections through the letter grade earned for the group project.

	Enrollment	Average Score	Std Dev	Median Score	Letter Grade
Section 1	52	89.93	2.95	89.89	B+
Section 2	62	87.79	5.47	88.72	B+

Table 13: Comparison of student performance in Sections 1 and 2 (T-test: t = 2.65, nu = 96, p>0.05)

5. Discussion

a. Student Performance

A quick look at Table 13 reveals only a minor difference—in terms of average or median scores—resulting in the same letter grades of "B+" for students in either *Section 1* or *Section 2*. However, it should also be noted that though inconsequential for the average letter grade, the average score difference is nevertheless statistically

significant [12] for a chosen significance level of *p = 0.05.* Indeed, the data of Table 13 yields a test statistic of *t = 2.65* with degrees of freedom *nu = 96* resulting in a p-value greater than the assumed significance level.

b. Student Level of Satisfaction

i. Team assignment

Looking at the pre-project survey results from both sections for the first question (see Table 5), students in *Section 1* appear to be happier with their team assignment (average rating: 8.57 out of 10) compared to their peers in *Section 2*—average rating of 7.94. The corresponding T-test statistic is *t = 1.55* with degrees of freedom *nu = 89*, resulting in a p-value less than the assumed significance level of *0.05*. In other words, it is statistically significant that students in Section 1 are one average more satisfied with their teammates than those in Section 2. This is to be expected as teams in *Section 1* are self-formed whereas those in *Section 2* are assigned, the former being inevitably based on familiarities and friendships within the classroom.

After completion of the project, the average rating in *Section 1* increases to 8.59 while that of *Section 2* increases to 7.96—see Table 7. However, unlike pre-project survey results, this difference is no longer statistically significant at a significance level of *0.05*. Indeed, the corresponding T-test statistic is now *t = 1.18* with degrees of freedom *nu = 48*, resulting in a p-value greater than the chosen significance level. In light of the pre-project survey results, this indicates that while students in *Section 1* were happier with their teammates before the start of the group project than those in *Section 2*, this difference is no longer significant at the end of project. In other words, students in *Section 2* experience improved levels of satisfaction with regard to their team assignments compared to their peers in *Section 1*. It is worth pointing out that this is so despite the fact that the average team satisfaction level remains unchanged in both *Section 1* (see Table 9 where *t = 0.05. nu = 37*, and *p>0.05*) and *Section 2* (see Table 11 where *t = 0.04. nu = 44*, and *p>0.05*)

ii. Ease of working with teammates

Question 2 of the pre-project survey asks students for the ease with which they anticipate working well with their teammates. The data of Table 6 (*t = 1.55, nu = 89, p>0.05*) reveals no statistically significant difference between the responses of students *Section 1* compared to those of students in *Section 2*. The same is true when comparing post-project survey results for both sections. In this case (see Table 8), the test statistic is *t = 0.30* with degrees of freedom *nu = 46*, resulting in a p-value greater than *0.05*.

In light of the above, it would appear that our prediction of improved team dynamics in *Section 2* compared to *Section 1* after completion of the group project proves untrue. Though this is the case, it is worth noticing that team

dynamics in *Section 1* deteriorates in a statistically significant manner (see Table 7 where $t = 1.38$, $nu = 29$, and $p<0.05$) whereas there is no statistically significant difference when comparing answers to Question 2 (Q2) for pre- and post-project survey results in Section 2—see Table 12 where $t = 0.83$, $nu = 41$, and $p>0.05$. This is also reflected in the respective median score as that of *Section 1* decreases from 9 (pre-project) to 8 (post-project), while that in *Section 2* stays constant at 8. Put differently, the answers to Q2 suggest that over the duration of the project, team dynamics in *Section 1* worsens while it is unchanged in *Section 2*.

c. Limitations

Though the results of the present study do not confirm all the hypotheses stated earlier, it is nonetheless the case that, as predicted, the group forming scheme presented in this paper led to improved team satisfaction levels for students in *Section 2* compared to their peers in *Section 1* with no significant advantage in terms of improved team dynamics. However, it is crucial to remember that in the form described here, the above group forming scheme has only been implemented to one aerospace engineering course consisting of two sections. Hence, to more adequately capture the efficacy of the proposed scheme, it is essential that it be implemented in multiple courses across engineering disciplines and universities. This point is especially important since the student demographics involved in this study was not diverse in terms of racial or gender identity—see Tables 2 and 4.

Finally, we also recognize that there is some element of subjectivity in the proposed method as it is likely that different instructors may form different teams from the same set of responses to the survey of *Appendix A*. That said, the point of this study is that despite such differences, the resulting assigned teams will still perform no worse than teams where students are allowed to self-select and their level of satisfaction will improve comparatively over the duration of the group project.

6. Conclusion

As engineering students graduate and enter the workforce, it is expected that they possess teamwork and collaboration skills necessary for long-term success in the field. This is especially important today as engineering often requires collaboration between people of different backgrounds and cultures. Therefore, exposing students to such diverse team experiences plays a crucial role in getting them ready for the engineering workforce. In this study, we described one attempt to forming such diverse teams with a focus on equity in terms of skills as well as, to the extent possible, gender and racial identity. In an effort to test the efficacy of the proposed method, we compared two sections of an aerospace engineering course, one where the method described here was used to assign students to teams and the other where it is not. Findings suggest that after completion of the group work, students in assigned teams (as done in the present study) exhibit improved levels of satisfaction with original team assignment with no effect on team dynamics. Moreover, while students in the self-selected group report higher levels of initial satisfaction with team

dynamics, those levels decrease after completion of the group work. Based on these findings, we suggest that forming teams according to the methods outlined in the present work provides positive experiences for students and, compared to the alternative of self-formed groups, potentially more fully prepares them for success beyond the classroom.

Admittedly, the above conclusion follows from implementing the proposed method in a single course. Therefore, implementing the method in multiple engineering courses across multiple disciplines would help determine the effectiveness of the method more convincingly, especially in light of its inherent subjectivity in forming teams. Importantly, because assigning teams might be perceived as disempowering to students—at least initially—engineering educators should work to be transparent in their team formation practices and explain to students the rationale for such approaches.

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Appendix A

Goal: Answers to the following questions will be used by the instructor to form teams while making sure that (i) each team has appropriate representation in terms of skills needed to have a successful project and (ii) no URM (gender or ethnicity) student is the only such person in a group.

For questions 1 through 8, select the answer with which you most identify.

1. Which of the following most closely describes you?
    a. Dependent (I usually count on my teammates to help me complete a task)
    b. Reliable (I usually do what is expected of me in a group setting without reminders from others)
    c. Leader (I usually go the extra mile to help my team successfully complete a task)

2. Which of the following do you value more?
    a. Collective effort (collectivism)
    b. Individual effort (individualism)

3. Gender identity:
    a. Male
    b. Female
    c. Non-binary
    d. Prefer not to disclose

4. Which of the following motivates you most?
    a. Proving to myself my ability to become a successful Aerospace Engineer
    b. Proving to my friends and/or family my ability to become a successful Aerospace Engineer
    c. I know what I am capable of accomplishing and do not need proving it to anyone.

5. In your opinion what is the role of an Aerospace Engineer with regard to social justice?
    a. None (I do not see a connection between Aerospace Engineering and issues of social justice)
    b. Limited (It is possible that Aerospace Engineers could be drivers of social justice, but I don't see how)
    c. Somewhat important (I think Aerospace Engineers play a
    d. Important (Aerospace Engineers should be aware of issues of social justice in their design work)
    e. Very important (Social issues, among others, should guide the design considerations of an engineering team)

6. Areas of potential contribution to AERO 320 group work (select all that apply):
    a. Engineering Dynamics (application of Newton's 2nd law to rigid bodies in translation and/or rotation)

b. Linear algebra and ODEs (matrix manipulation, eigenvalues/eigenvectors, solving first order ODEs and systems of ODEs, etc.)
c. Numerical Analysis with *Matlab* (familiarity with coding in *Matlab*, solving ODEs and systems of ODEs numerically, etc.)
d. I'll do what's necessary to help the team succeed

7. Racial identity:
    a. Asian or Asian Indian
    b. Biracial or Multiracial
    c. Black/African
    d. Hawaiian or other Pacific Islander
    e. Hispanic/Latinx
    f. Indigenous or Native
    g. Middle Eastern or North African
    h. White
    i. Prefer not to disclose
    j. Other. Please specify.

8. I tend to see myself most as:
    a. Independent (distinct from other people and act freely based on personal motives, goals, and preferences)
    b. Interdependent (connected to others and respond to the needs, preferences, and interests of others)

9. Is there anything else you are worried about in taking part in the numerous group activities for this course? Please specify.