A hybrid approach to team-forming for capstone design projects

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A Hybrid Approach to Team-Forming for Capstone Design Projects

Abstract

One of the challenges for capstone design instructors is forming equitable, balanced, and appropriately-skilled student teams to work on projects for a year. For most capstone programs, there are three main parts of this process: identification of projects, presentation of projects to students, and selection of student teams. This paper focuses on the third part: While there is significant useful research about the best ways to form student teams, capstone design team formation has unique aspects that are not directly addressed by much of the prior work. In particular, what is the best approach for team-forming when the participants have similar skills but are deployed to work on very different design challenges? In our capstone course, we recently compared two approaches to team formation: Student-formed and faculty-formed teams. The results of this comparison are reported in a separate paper. This year, informed by these results, we implemented a new hybrid team-forming process designed to retain the student agency resulting from student-formed team while addressing some of the concerns of this approach.

This paper summarizes relevant team-forming research and results from our past approaches to forming teams. Then we describe the hybrid approach implemented this year and analyze the preliminary results obtained after one quarter of student teamwork (including student surveys focus groups, and team peer evaluations).

Background

There are many different approaches to team formation described in the literature (see Barkley *et al*. [1] for review), including random assignment, self-selection, and instructor assignment. In a large course (e.g., 50 projects and 160 students), the process of forming teams is particularly challenging [2]. There are some algorithms (www.catme.org) that have been developed to try to improve this process by considering a specified set of parameters [3], but these processes leave students with minimal agency in the final decision. Despite the best efforts of faculty, students are sometimes unhappy with their assigned team and/or project. This dissatisfaction, if unchecked, can result in poor team performance and negative student experiences.

Believing that choice is the primary factor in student motivation [4], and that student motivation leads to high team performance and positive experiences, faculty in the Cal Poly San Luis Obispo Mechanical Engineering Department have experimented with different approaches to forming teams in our year-long senior design project courses. With a large number of students and projects starting each year, we have an opportunity to make changes and gather a lot of data about their results. The three approaches we have implemented are:
- Faculty-formed teams, using a student survey and off-line team formation
- Student-formed teams, based on the Mingling Method described by Aller *et al*. [5]
- Hybrid-formed teams, an adaptation of student-formed teams that leaves the final team-forming decision in the hands of the instructors

All of these team-forming approaches start before the first term begins by providing students with project proposal descriptions, sponsor contact information, and guidelines on what to consider when looking at potential projects (e.g. personal interest, career goals, prior experience, special skills, anticipated workload). This material allows students to start thinking about the type of the project before classes begin. At the first class meeting, after discussing course logistics, explaining the team-forming process, and answering questions, students attend a 'Sponsor Q&A Expo' where they meet with sponsors of projects they are interested in. Following this Expo, we move into the team-forming process.

Team-Forming Approaches

Faculty-formed: Our traditional method of team-forming has faculty forming teams based on students' self-identified interests and preferences. The process consists of:
1) Students complete a project preferences survey identifying project interests, skills, time availability, and optional team preferences (students can identify up to three students they would prefer TO or NOT TO work with)
2) Faculty use these surveys to form teams of interested students off-line. Team preferences, if stated, take precedence over project preferences. This is a dynamic process involving lots of time and stacks of student surveys spread over tables.
3) Project teams are announced by email and team members meet each other in the next class period.

The faculty-formed process follows many of the recommendations for student team formation in the literature. However, it suffers from a few drawbacks:
- Students don't feel like they have control of the process. Student feedback has shown they often feel that their project/team assignment came from a lottery, rather than from their reported preferences.
- The process takes a significant amount of time and effort from the faculty (8-12 hours in a typical term).
- While most students will be assigned to one of their top 10 projects, less than 25% typically get their first choice.
- There is no opportunity to adjust teams to avoid interpersonal issues. Some students who experience team issues have reported that they knew these would occur from the moment they first met their teammates.

Student-formed: In an attempt to overcome the observed issues with our faculty-formed process, starting in Fall 2018, a new Student-formed teaming approach was implemented. In this approach, students were more directly involved in selecting their project and team. This process consists of:
1) Students complete an online survey to rate projects and self-identify skills.
2) Faculty use survey results to assign projects to specific times (Senior project labs meet at up to three different times, and we have chosen not to initially restrict student choice by limiting the projects to specific times).
3) In lab, faculty guide students through an interactive team-forming activity (Figure 1):
   a. Faculty place posters for all projects available at that time around the room, with special skills identified.

b. Students place name tags (sticky notes with their names) on posters for their top two projects.
c. While placing name tags, students meet others interested in the same projects.
d. Students could move their name tags until they found a project/team combination they were happy with.
e. Projects are restricted to teams of 3-4, so faculty occasionally intervene to encourage students to disperse from popular projects.
f. As appropriate sized teams are formed, they are sent outside to have a first team meeting.
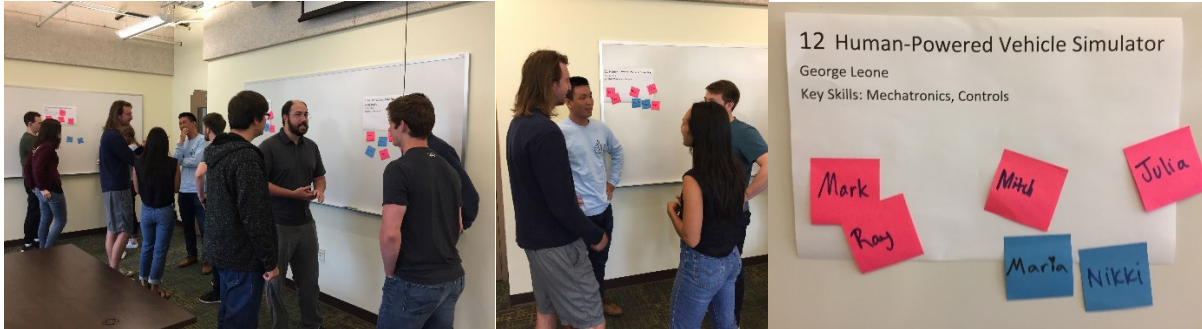

Figure 1: Student-formed Team Process in Action

The student-formed process addressed several of the drawbacks of the faculty-formed process:
- Students had direct involvement/control of their teams,
- Faculty spent far less time forming teams (but more class time was needed)
- Students could 'pre-screen' their team members
- Over half of the students were able to work on their top choice project

However, some concerns were observed during team-forming:
- Some students felt pressured by their peers to move off of popular projects.
- Students felt there wasn't enough time to 'speed date' potential team members in class.
- As completed teams left the room, remaining students felt that they needed to 'hang on' to their project or be left with no choice.

In addition, we observed that student-formed team peer reviews were slightly lower throughout the course of the project.

Please see [6] for more complete descriptions of the faculty-formed and student-formed processes, in addition to data on the effects of these two types of team-forming on the student experience in senior project. The rest of this paper presents a new hybrid approach developed to address the shortcomings of these two alternatives.

Hybrid-formed: In Fall 2019, we implemented a hybrid process, blending the best aspects of the faculty- and student-formed processes. While overall similar to the student-formed process, the hybrid-formed process returned the final team decisions to the faculty. The process consists of:
1) Students wear nametags during the Sponsor Q&A Expo visits to help meet & identify other interested students.
2) Students complete an online survey to rate project interest, self-identify skills, and identify students with whom they would have a problem.

3) Faculty use survey results to assign projects to specific labs and identify popular projects.
4) Students are encouraged to change lab times if desired to access different projects (subject to capacity limits).
5) Project posters and sticky notes are posted the day before lab so students have extra time to meet other interested students and move their names around (instructions in Figure 2).
6) In lab, faculty guide students through an interactive team-forming activity (Figure 3):
    a. Students place name tags (sticky notes with their names) on posters for their top three projects.
    b. While placing name tags, students meet others interested in the same projects.
    c. Students could move their name tags until they found a project/team combination they were happy with.
    d. Students could stick their name tags to other students' to identify preferred teammates.
    e. If projects have too many name tags, faculty encourage students to move or ensure other choice projects are 'lightly' tagged.
7) After 45 minutes, faculty remove posters and use them to form teams while a guest speaker addresses the class. The earlier student survey results are used to avoid known team member conflicts.
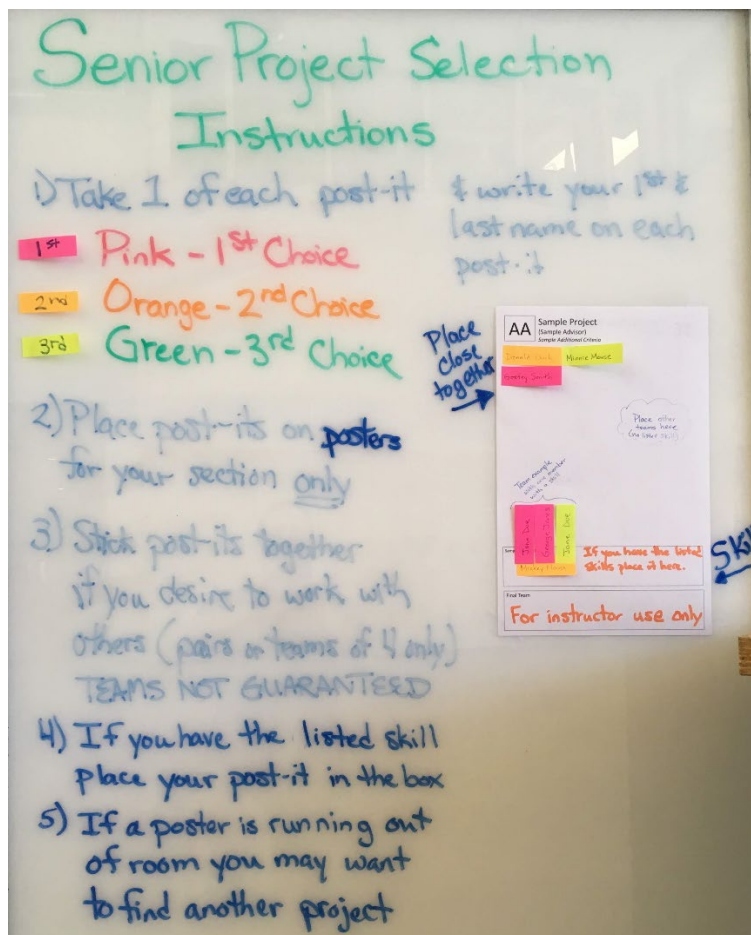

Figure 2: Hybrid-formed Teaming Process Instructions

Figure 3: Hybrid-formed Teaming Process in Action

The hybrid process attempted to remove the three team-forming issues identified in the student-formed process in these ways:

- By removing the final team formation decision from the students' hands, we hoped to remove the risk of students feeling pressured to change their project votes.
- By allowing the students to post stickers early and meet students, we increased the amount of time for project/team 'speed-dating.'
- By not removing completed posters, students would not know which projects they might be 'missing out on,' removing this pressure.

We hoped that since the students weren't generally forming their own teams, they might be less critical of their teammates during the process (resulting in higher team peer reviews).

Evaluating the Process

Although the hybrid-formed teams are still working on their senior design project, we have begun to collect data to determine if the process improvement goals are being met. Three sources of data are being collected to assess the impact of the team-forming process on the student experience:

- A team-forming process survey, conducted a few weeks after teams were formed.
- Team-forming process focus groups, taken from volunteers on the survey.
- Team peer assessments, conducted twice each quarter. Two are complete as of now.

Current results from each of these will be discussed in turn.

Team-Forming Process Survey

A team-forming process survey was given to students a few weeks after the teams started working together. The same survey questions were previously used with the student-formed teaming process, and the results of both are compared. The surveys had high response rates for both groups: 77% (102/133) for the student-formed teams (September 2018) and 89% (141/158) for the hybrid-formed teams (September 2019). While many of the responses from the two cohorts were very similar, there were some differences.

Question 5 addresses one of the key goals for the team-forming process: Matching student interests with projects. The responses (Figure 5) show that even though students on the hybrid-formed teams were not able to make the final team/project decisions, nearly 50% of the students

ended up on their first choice project, and over 80% were assigned to one of their top three. There is no statistically significant difference between the two groups.

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1) How would you describe your emotional state during the team-forming process? (check all that apply)
Very stressed. A little stressed. Worried about finding out what my project would be. Excited about finding out what my project would be. Excited about finding out who my teammates would be. Worried about who my teammates would be. Calm. No different than starting any other new class or project. Happy that I had some control over choices of team and project.

2) What strategies did you use during the team selection day? How important was each strategy to you? (check all that apply)
Chose to be on a team with my friends. Avoided being on a team with certain people. Chose my favorite project and refused to move. Put priority on specific projects. Chose to be with team members who I thought were very hard working. Chose to be on teams I thought would be very diverse. Other strategies. Importance: Very important, Somewhat important, Not very important, No importance at all.

3) With what you know now, would you have changed your team selection strategy? If so, how?

4) What aspects of the teaming process were most concerning to you?

5) Was the project you ended up on one of your top choices?
My top choice. One of my top three choices. One of my top six choices. My seventh choice or higher. Not that important to me – I was more interested in my team.

6) Now that the project is underway, are you happy with your project choice?
Very happy with the project. Somewhat happy with the project. An even mix between happy and unhappy with the project. Somewhat unhappy with the project. Very unhappy with the project.

7) How happy were you with your teammates at the time of selection?
Happy with all team members. Happy with most team members. An even mix between happy and unhappy with my team members. Unhappy with most team members. Unhappy with all team members.

8) After working with them for a few weeks, how happy are you now with your teammates?
Happy with all team members. Happy with most team members. An even mix between happy and unhappy with my team members. Unhappy with most team members. Unhappy with all team members.

9) Rate your level of agreement or disagreement with the following statements:
   a. The process for assigning teams was equitable for all students
   b. This process should be used in senior project in the future
Agreement: Strongly Agree. Agree. Slightly Agree. Slightly Disagree. Disagree. Strongly Disagree.

10) How important was it for you to have some say in these decisions for your senior project:
   a. Choosing the project I work on
   b. Choosing the team I work with
   c. Choosing my project advisor/coach
Importance: Very important, Somewhat important, Not very important, No importance at all.

11) Do you have any suggestions for improving this process if we use it again?

12) Are there any other comments you would like to share?

Figure 4: Team-Forming Process Survey Questions

Question 7 addresses one of the other team-forming goals: Forming compatible student teams. The results (Figure 6) show a similar distribution of responses for the two groups, with slightly less initial team satisfaction for the hybrid-formed teams, as expected. These differences are not statistically significant.
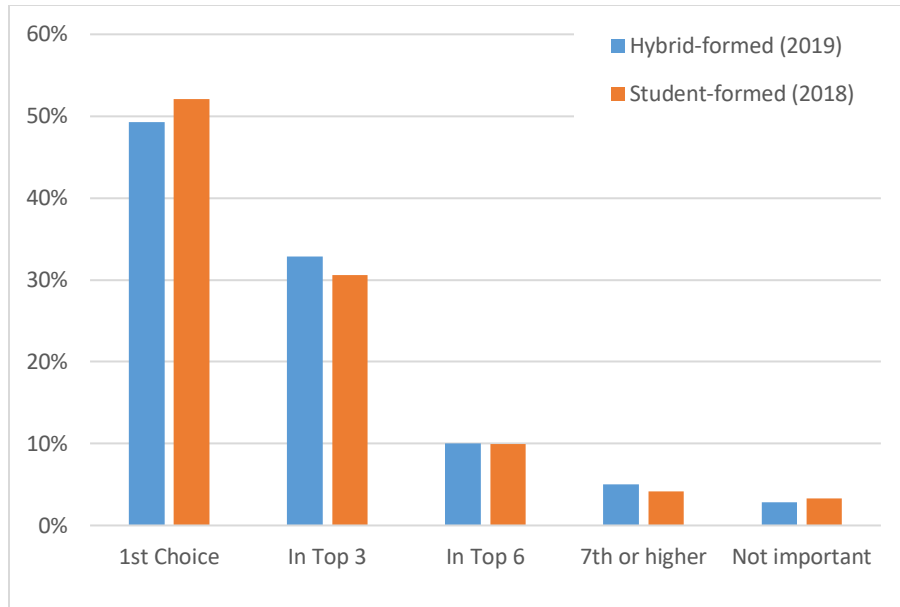
Figure 5: Team-forming survey: Percentage of students assigned to one of their top-ranked projects
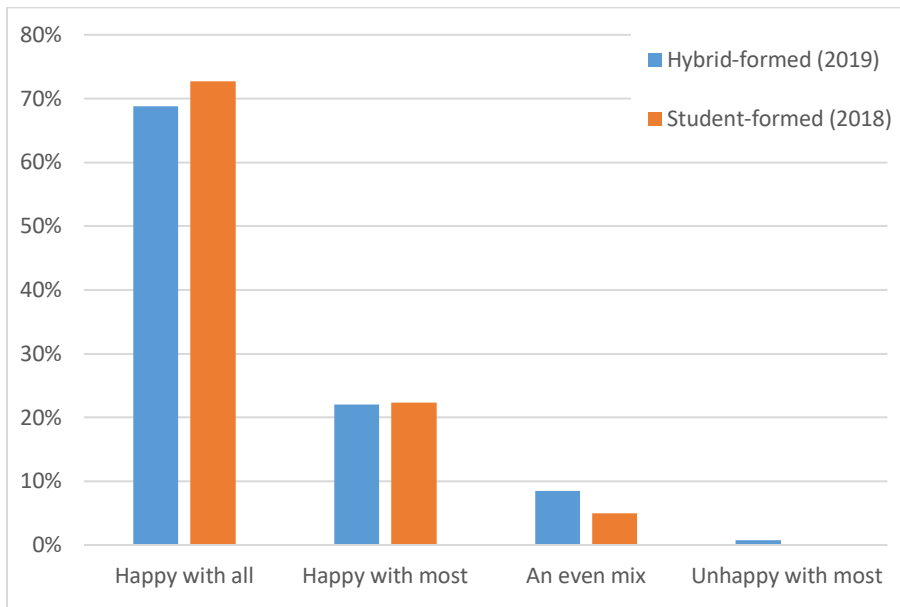

Figure 6: Team-forming survey: Percentage of students initially happy with their teammates

Question 1 gives some insight into the student experience during team-forming. In the student-formed cohort, 22% of students reported feeling "Very stressed" during team-forming. In contrast, in the hybrid-formed cohort only 14% of the students reported this high stress level (though a greater number reported feeling "A little stressed").

Question 9(a) provides an opportunity to gauge students' perceptions about the process. One of the concerns with the student-formed teams was that some students felt that the process used was not equitable for all students (due to pressure felt during team-forming). By removing the final

team decision from the students, the hybrid team-forming process improved this perception: 86% of the hybrid-formed cohort felt the process was equitable (strongly agree, agree, slightly agree), compared to 74% of the student-formed cohort.

A final concern with the student-formed teaming process is that it might result in lower team diversity, assuming students might be inclined to select teammates who appear similar to themselves. Since our survey did not ask for a respondent's team, we cannot relate students' self-reported ethnic and gender identity with team membership. However, in question 2, we did ask students how much importance they placed on team diversity when forming their teams. The results are shown in Figure 7. As expected, most students did not place a high importance on diversity during team-forming.
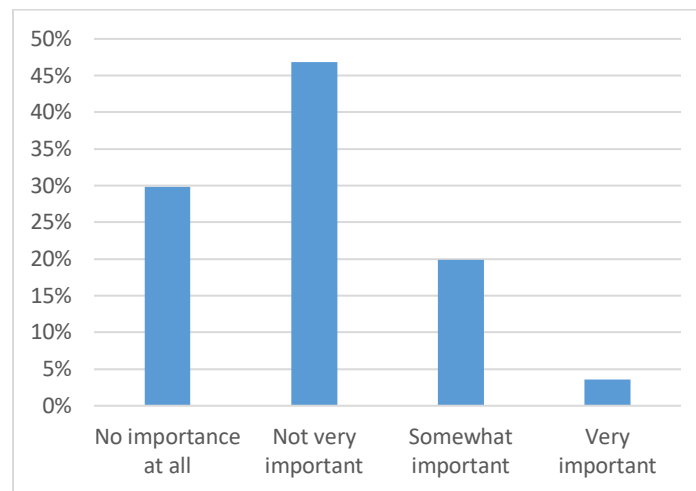

Figure 7: Team-forming survey: Importance of diversity to students while forming teams

Team-Forming Process Focus Groups

To better understand the various team forming approaches used by students, as well how the process influenced students' overall experience, we conducted two focus groups in Fall 2019. Each focus group had four students from senior projects, none of whom were on the same project team. The focus groups were conducted by a Mechanical Engineering Department faculty member who is familiar with senior projects but not currently serving as a project sponsor or advisor. Each 60-minute focus group was audio recorded and then professionally transcribed to prepare the data for analysis.

During the focus groups, these four questions were posed to the students:

1. Knowing what you know now, would you change the approach you used to select your team or project?
2. In what ways did the team forming experience contribute to your satisfaction with your team?
3. What most affected your overall experience on senior projects – you team, your project, your sponsor, or your advisor?
4. If you were in charge of senior projects, how would you assign teams?

Major themes and illustrative quotes generated from the students' responses to these questions are presented below.

Overall students were satisfied with the hybrid approach to team forming. Granted, at the time of the focus groups, they were in their first quarter of Senior Projects and still adjusting to their teammates, project advisor, and the course in general. Students did express that they initially felt frustrated and disappointed when they didn't get matched up with their first-choice project, but all students in both focus groups did get matched up with one of their top three projects. In terms of strategy, most students described prioritizing teammates over the project. In other words, students preferred to work on a team with people they like over working on a top-choice project with people they didn't like. The students felt that this trade-off (people vs. project) resulted in few students feeling extremely satisfied, but many students feeling somewhat satisfied.

> "I'm fairly satisfied with the whole process, but I wouldn't say I'm totally satisfied either. Neither in the project that I have or the group that I have, but I'm adequately satisfied."

> "The project I have now definitely wasn't my first choice, but I like it so much now because I like how our team is, and I feel like we've bonded well. I like us working together more than whatever project we're on.

Students expressed the value of having some control over the team-forming process. They preferred this method to having purely faculty-formed teams. Students also valued having time in between when the projects were announced and when they needed to finalize their team choice. They used this time to think more about the projects, read about the projects and sponsors online, and – perhaps most importantly – talk to other students who were also interested in their top-choice projects.

> "Those couple of days, I thought, were really good because after the first day I didn't want to make any decisions of who I was going to be on a team with. But after talking over the project and talking to other people about the project and everything, I thought we'd be a really cool team."

Not only did this process allow students to discuss their individual skills and experiences related to the project, it gave them enough time to gauge their chemistry with potential teammates. Some students described feeling very certain about their top-choice project, until they interacted with other interested students, for whom they did not feel positive chemistry.

Students also expressed how valuable it was to have the project sponsors come to campus to speak with them personally about the projects. Some students described not feeling interested in certain projects until they spoke directly with the sponsors.

> "There were some projects that I wasn't even very excited about, but I talked to the sponsor and was like 'I would love working for you. I don't even care what we're doing.' "

However, it seems as though some companies sent representatives, rather than a more vested sponsor, to meet with the students. The students felt that the representatives lacked enthusiasm, and recommended that the true project sponsors try to attend this first meeting.

Other recommendations made by the students included senior project faculty creating a roster with student names, pictures, and enrolled section. This would have helped students form teams, given that faces are generally easier to remember than names. Students also suggested the creation of a team forming app that would take in students' survey data, schedule, and other preferences, then recommend 10 potential teammates. Students described this app as something between a more formal team-formation software (i.e. CATME) and an online dating app. Lastly, students suggested that senior project faculty describe the process they used to make the final decision about the teams so that the whole process has maximum transparency.

> "I think the more freedom you give students and the more ability they have to choose, the more satisfied they'll be. If I had gotten a project I didn't like, but I had choice, or the ability to choose, I would make the best of it knowing I had the ability to shape how I got here."

Team Peer Evaluations

Capstone design students are asked to peer review their teammates twice per quarter throughout their project. The aggregate results of this survey can be used as a measure of whether team interactions (and by inference, student experiences) was affected by the method of team-forming, by comparing the team feedback data from the two groups. Because these surveys are required to be submitted, the response rates were over 90%. The peer review survey consists of students indicating their level of agreement (Likert scale) with 15 positive statements about each of their team members. Since all statements describe positive team member characteristic, a score of 1.0 is the 'best' result. For the purposes of this study, the results were averaged over all students in each group, rather than looking at specific teams. In order to make the numerical results easier to interpret, the mean Likert scores were converted to a measure of team satisfaction using a linear scale where 1.0 indicates complete (100%) satisfaction and 5.0 indicates no (0%) satisfaction. The statements can be grouped into three categories:

- Team Identity and Mutual Respect
- Individual Productivity
- Communication

Hybrid-formed teams have submitted peer feedback only for their first two quarters (four surveys). These results are compared to the corresponding first four surveys for the student-formed teams in Table 1.

The results for both groups show high team satisfaction overall, with the results gradually increasing throughout the project. There is no statistically significant difference in team satisfaction between the two team-forming methods. In other words, the hybrid team-forming approach did not result in any improvement in team satisfaction (but also did not reduce it).

Table 1: Peer Review Surveys – Average Team Satisfaction

	Team Identity		Productivity		Communications	
	Hybrid	Student	Hybrid	Student	Hybrid	Student
Survey 1	91%	92%	92%	92%	86%	86%
Survey 2	92%	92%	91%	93%	87%	89%
Survey 3	92%	92%	92%	92%	89%	89%
Survey 4	93%	93%	93%	92%	90%	90%

Discussion

The student-formed teaming approach used for our mechanical engineering capstone design course in 2018 showed promise compared to our previous instructor-based method. In particular, we found that students had more agency in the process, more students were assigned to their first-choice project, students could pre-screen potential teammates, and less faculty time was needed to form teams. However, there were a few concerns observed during the student-formed process implementation. In response, in 2019 we modified the approach by returning the final decision about team membership and project assignment to the faculty. At this point (2/3 of the way through the project) the new process appears to have reduced most of the observed concerns:

- Peer Pressure. The hybrid team-forming process resulted in a decrease in the amount of peer pressure students felt during the in-lab team-forming activity. This was observed by faculty during the event. In addition, this likely contributed to the increased number of students who felt the process was equitable and the fewer number reporting high stress.

- Time Pressure. The hybrid team-forming process allowed students more time to meet each other and discuss projects. Students highlighted this benefit during the focus group discussions.

- Project Pressure. By not removing projects after complete teams were formed, we hoped to reduce the pressure students felt about missing out on a project. While we did not have a direct question about this (and students in the focus group didn't know what they missed!), the reduction in the number of students reporting high stress levels is a good indication that this process change was a good move.

- Team Satisfaction. Team satisfaction, both right after team-forming and as measured by the periodic peer reviews, is high for both the student-formed and hybrid-formed cohorts. While this means both are slightly lower we previously measured with faculty-formed teams, the difference is very small.

It appears that the changes we implemented in the hybrid-formed teaming process have been successful in addressing the concerns observed with the student-formed process. We will continue to monitor the student feedback for the rest of this cycle and document final results after the projects are completed.

Conclusion

Student team-forming for capstone design projects can be challenging. This paper describes a hybrid process for forming teams that gives students more agency in the process, but attempts to remove some of the risks of having them form their own teams. The process was used to form teams for a student cohort that started in September 2019 and assessment of this approach is on-going. Preliminary results indicate that it retains many of the positive attributes previously seen with a student-formed teaming approach, such as high student placement on first-choice projects and students feeling more in control of the process. At the same time, it appears to have removed most of the negative issues observed when students were given full control over final team formation. Interestingly, teams formed with the hybrid approach and the student-led approach seem to have slightly lower team peer evaluations throughout the project when compared to their counterparts who were on teams formed by faculty. This is a minor difference, but it is worthy of further investigation.

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