# An Analysis of Freshman Teamwork Experiences in Required Design and Entrepreneurial Thinking Project-Based Learning Courses

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Project-based learning in a team setting can be a significant platform in engineering curricula for collaborative learning, engagement and student retention of learned material. While several practices for team formation are evident in literature, a limited number focus on maximizing student satisfaction while working in teams. This is critical for first-year students who just entered college in a competitive admissions process and often require some learning to understand collaboration in a team setting. At Stevens Institute of Technology (Stevens), we have analyzed the freshman team experiences in three-major core engineering courses, and this paper presents example practices that have promoted positive teamwork experiences as well as quality project outcomes.

In this study, we used team assessment data from three courses from the same cohort of students (214) across multiple sections in the 2017-2018 academic year; first-semester design course on basic electromechanical systems and robotics in the fall semester, second-semester design course on fielded systems, and the introductory course on entrepreneurial thinking. All courses used project-based learning with teams of three or four students. A software tool and its built-in methodologies (CATME) were used to assess overall satisfaction with their teammates, which we adopted as a measure of student satisfaction from their team experience. Major differential factors in our study included, whether the students were given a project by the instructor or allowed to define their own project; and if they had any choice in selecting their teammates. In the first-semester design course, students were sorted in teams using a hierarchical set of policies defined in CATME's Team-Maker and were assigned a project for the semester; all students in the course worked on the same project. In the second-semester design course, students were able to pick their teammates with a few restrictions, but a project was assigned to them. The students in the entrepreneurial thinking course selected their teammates and their project with the constraint that it must follow a theme of social innovation. While traditionally it is challenging to maintain quality when students define their own project, instructors reviewed the student project proposals and established a level of the quality and scope for the projects. Small class sizes (less than 28 students), flexible teaching methods, standardized evaluation rubrics, and flipped classroom methods are all used to ensure the learning objectives for these courses are consistently met across the sections.

Overall group satisfaction was 5% higher in the entrepreneurial thinking course than second-semester design course and 8% higher than that of first-semester design course. We found that prior experience of working in teams enhances the satisfaction score as evident from the increased ratings from first to the second-semester courses. Additionally, when looking at the engineering design courses that had the same subset of instructors, 83% had improved team satisfaction with a 7% average increase in the second course, when compared to the first.

## Introduction

Considerable research and adoption of research outcomes have gone into improving the first-year engineering curriculum nationwide. A majority of engineering students leave school after their first year [1]. Traditionally this was referred to as the thinning of the herd; students are convinced to leave engineering programs because they cannot manage the academic workload. Attrition studies have concluded that most students that choose not to remain in engineering are

doing well academically and have GPAs similar to those students who stay in engineering courses [2,3]. These studies refer to outdated curriculum and a misunderstanding of how students prefer to learn [4, 5, 6].

Project-based team learning is an essential practice used to modernize engineering curricula and has been shown as a decisive factor in retention of students in STEM fields [1]. Working in teams brings along its own set of problems, however, studies by Oakley et al., indicate that the quality of learning is improved for students [7]. Best practices in assessing teamwork support using tools like the "Comprehensive Assessment of Team Member Effectiveness (CATME)" to allow students to evaluate and reflect on team members [8].

Shepard has noted that when students are interested in the subject area of projects, students tend to have higher satisfaction [9]. In non-discipline specific courses, it can be challenging to design a project that piques the interest of all students. Some, like Shepard, will opt for giving the students a choice of projects. Most professors do not allow students to design and choose their projects, as it can be tough to achieve engineering learning and grading rubrics can be challenging. Even having a few options for students, can be a substantial workload for professors, and require additional training for adjunct instructors. At Stevens, we are unable to allow students to choose a project in either of our multi-section, multi-instructor first-year engineering design courses.

However, entrepreneurial thinking is a more flexible topic that can enable students to select their project and also learn to apply these valuable skills. We propose that students will have a more satisfying team experience in an entrepreneurial thinking course, than a design course, since the concepts can be taught to almost any project. There is a push for incorporating entrepreneurial thinking and an entrepreneurial mindset in freshman engineering courses [10] as employers find these skills desirable in graduates.

We have a separate stand-alone course which has an entrepreneurial project to help students have a positive teamwork experience and also learn and apply valuable entrepreneurial thinking skills in the freshman year. For this paper, we have analyzed the freshman team experiences in the three-major core engineering courses and are presenting our examples that have promoted positive teamwork experiences while maintaining the quality of the projects and providing consistent learning objectives.

Teamwork as a freshman – our courses

Most freshman that come to Stevens have achieved very high individually and working in a team is a new experience that may take some time and practice. To understand the freshman experience we decided to look at how their team experience was perceived. Students take two engineering design courses sequentially in the first year which offer project-based learning, Engineering Design I (ED1) and Engineering Design II (ED2). Additionally, we have a required course called Introduction to Entrepreneurial Thinking (MGT1) which is a required course for engineering students in the spring of the freshman year, taken concurrently with the second design course. All three courses have the majority of the work in teams, and we used CATME peer evaluation tools to get a common metric across three courses. All engineering disciplines are required to take these courses, which results in 457 students in the freshman cohort for Fall 2017 to Spring 2018.

ED1 introduces students to the process of design and seeks to engage their enthusiasm for engineering. This is a two-credit laboratory course that meets in our design laboratory that is equipped with workbenches and tools. The capacity for the course is 24 students. Students work in groups of three, giving an instructor a maximum of eight groups per section. We had six instructors teaching a total of 22 sections for Fall 2017, some adjunct professors teaching just one course, and full-time faculty teaching up to six sections of this course. The instructors that teach this course have been doing so for over six years and meet only once at the beginning of the semester and once in the middle of the semester. Students are assigned to teams using CATME team maker based on prior experience in programming. Freshman students come into Stevens with a variety of experience levels; some students have been competing in FIRST® Robotics while other students have never touched an Arduino.

The course has a few introductory modules on the design process and then ties into other introductory courses in programming and graphics. The students work with all the same materials, robot kit of parts, and light sensors, with the goal of programming their robot to compete in a head-to-head competition. The students customize their robot and have access to 3D printers or a Laser Cutter to make custom bumpers for their robot. The winner is the first to knock out enemy targets (lights) without having their lights knocked out while avoiding obstacles. Students use C language to program a microcontroller to control the robot autonomously.

In ED2, students learn to design, build and field a weather station with multiple sensors and requires long-term data acquisition, processing, and deployment in the field. This is also a two-credit laboratory course that meets in our design laboratory. In Spring of 2018, this course was taught by the same instructors of ED1, with a few additional instructors. This course had new content in Spring of 2018, so there was more communication with instructors in the first few weeks. Additionally, bi-weekly conference calls took place to make sure instructors were on the same page and understood the new content. We had 21 sections total, and the capacity was also 24 students, the same as in ED1. For teaming for ED2, we allowed students to create teams with three restraints: They needed to ensure there were at least two majors represented on their team. One of the team members must have a windows-based personal computer. Thirdly, the team as a whole had to add their CATME scores from the previous semester to ensure a minimum threshold. Instructors were guided to help make teams if students were having a hard time forming.

Each team is provided a kit of parts consisting of a National Instruments USB data acquisition device, temperature & humidity sensors, potentiometers, and an Arduino-based micro-controller that is capable of publishing the collected data to an Internet of Things (IoT) server.

Throughout the semester, students learn how to use the various sensors to collect data and to visualize the data in LabVIEW. They also learn how to connect to various IoT devices and subscribe and publish data. They put all these skills together in the final project, which takes the last six weeks of the class, with the goal to create a field-ready weather station and to collect and analyze one week's worth of data.

MGT1 is a two-credit course headed by a course coordinator from the business school. He works with the Associate Dean of the engineering school to provide the course to all engineering

students. This course had 18 sections and was taught by ten different instructors in Spring 2018. Eight of these instructors are adjuncts from various business professions, some are strategy consultants, some are venture capitalists, and some are from our entrepreneurs-in-residence program. In this course, students work in groups of four, with a maximum enrollment of 28, so typically seven groups per section. This course is unique as all sections are on Fridays and it is only offered at two times. A morning session from 10 am to 11:50 am and an afternoon section from 1 pm to 2:50 pm. Each adjunct typically teaches two sections on Friday and then attends an after-action review meeting from 3 to 4pm. In this meeting, there is a debrief of how the course went that day, and then a content review for the coming week.

The course uses the lean-startup method and design thinking to provide a framework for students to solve a market need. Students come to the first class with a market insight and an idea for a new product. They form teams and as a team select which product idea to move forward with for the semester project. Students work in teams for the entire semester. This course has students learn to identify the point-of-view of the customer, by getting out of the building and talking to customers. Then they develop a minimally viable prototype to test the hypothesis of their product value to the customer. They must define the value proposition and the customer segment for the product. The students prepare a competitive analysis, and develop a lean canvas based on their product idea. The students do not go into a detailed financial analysis of their product, but they must demonstrate an understanding of how they will generate revenue. The course uses Ash Maurya's book Running Lean [11], to give the students a framework and example of the lean startup method. The course is delivered using flipped methodology, which allows for discussion and workshopping during class time, while students read and listen to lectures and take quizzes online as homework.

Most of the time the students have project ideas motivated by their everyday problems. They do not care to do the laundry in the dormitory, and they propose to work on a robot to do the laundry. They can use this idea to work on a lean canvas, even if the idea is simplistic. We have many coffee cups, alarm clocks, and cell-phone holders, that often turn into different ideas because the market is saturated and there is no real differentiation. Entrepreneurial thinking also allows students to fail, and still learn. The course allows for iterations of ideas, and some of the best projects completely change over time, as the students let go of their first idea, take the feedback from customers and try something new. For instance, the students who hate doing laundry, really don't like walking all the way down the stairs to find out all the machines are all being used. Their laundry robot turned into a notification app that allowed users to find out if laundry machines were in use.

Additionally, the rubrics and grading of the course does not benefit the team with the best idea. It is the team that travels the farthest to improve on their idea as well as follows the process of iteration. Customer interviews are graded and referred to by the professor in class. Prototypes, while not having to be market-ready, must show the features that test the value for the product. The main artifact for the course is a three-minute explainer video that demonstrates what problem the students are solving, what is the solution, what is the customer value and the stakeholder value.

In contrast to a traditional freshman design experience which has a limited set of expected results, in MGT1 *almost* any project can be chosen. The students have very positive reactions when they are told they can pick their project. At Stevens, the students do not select elective

courses until the fourth semester and the first two semesters look the same for each engineering student. This is the first time, students get to choose something of interest and they are also able to choose their teammates in MGT1. Instructors suggest that students pick a project idea that interests them, and also coordinate schedules based around commuting or athletics, which ends up helping overall team dynamics.

Results

When we started collecting and analyzing the data for these three courses in the freshman year, we were looking at a couple of things. The first was to see if the project and team selection had any effect on team satisfaction. Secondly, if working on a team becomes more satisfying over time. If a course that was technically more challenging was affecting team behaviors. Lastly, what section to section differences, or instructors to instructor differences could be seen in team satisfaction.

CATME peer evaluation tool gives a measure of team satisfaction. Each team member can rate their team members and their various contributions. It also asks some team satisfaction follow-up questions show below:

| | |
|---|---|
| Q1 | I am satisfied with my present teammates |
| Q2 | I am pleased with the way my teammates and I work together |
| Q3 | I am very satisfied with working in this team |

Figure 1. CATME questions

The students were in different teams and sections for all three of these courses. We used a data analytics tool, Tableau, to compare the mean response for each of these questions for each team experience in ED1, ED2, and MGT1. Students answer each question with a 5 being a high score and a low score of 1. Scores of 0 indicate a team member did not fill out the survey, and we did not use these responses for the whole team.

Figure 2 shows the results of the team satisfactions survey questions averaged individually and by the team. For example, the individual response average (averaged over 24 values in ED1 and ED2) is the average of the three-team satisfaction questions without regard for the team, and the team response average is averaged by the team in each course section (eight values per section in ED1 and ED2). The results show that the individual response average is lowest in the first class ED1 and then highest in MGT1. This data concurs with a study by Jones et all that allowing students to pick their projects and pick their teams can allow students to feel empowered and more engaged with their coursework [10]. The averages move higher from ED1 to ED2 which also shows that teamwork can improve over time and become more satisfying as an experience. This increase in the team experience score for students may also be based on the students had some choice in creating their teams in ED2. These instructors often have advanced business degrees and innovation backgrounds with extensive training in teaming. ED2 is technically more challenging than ED1, and it may be a reason or the increase as well, as teaming becomes more

critical as the technical challenges increase. It is hard to conclude if it is the course itself, or if the instructors play a role of why MGT1 is slightly higher than ED2. MGT1 is run with more collaboration among instructors with weekly meetings and a slack channel.

Figure 3 shows the first quartile (25 percentile) average values, which shows how the least satisfied teams are ranking. These values are nearly the same for ED2 and MGT1 for both individual and team averages, but the individual response is substantially lower in ED1 compared to the team scores, suggesting that some team members differ considerably on how satisfied they are with the team in ED1. For many students, this may be the first time they have ever worked on a team and therefore have no frame of reference. Figure 4 presents the ranges of all responses for individual satisfaction and team satisfaction, and the most varied responses come in the ED1 course, which also supports how a first-time team experience may be perceived by freshman students.

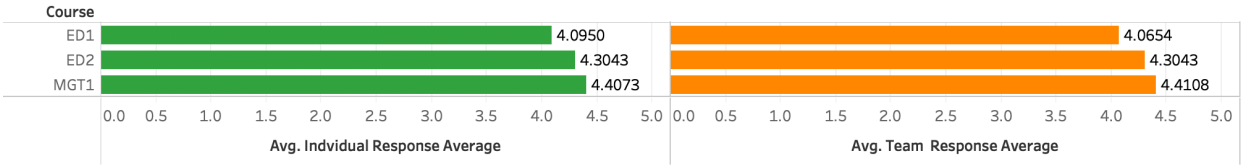


Figure 2. Team satisfaction: Individual average and team average for the team satisfaction survey questions.

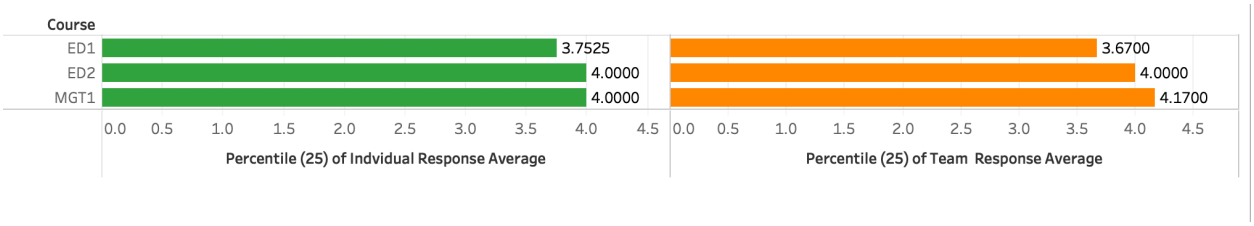


Figure 3. Team satisfaction: First quartile score for the individual and team response averages.

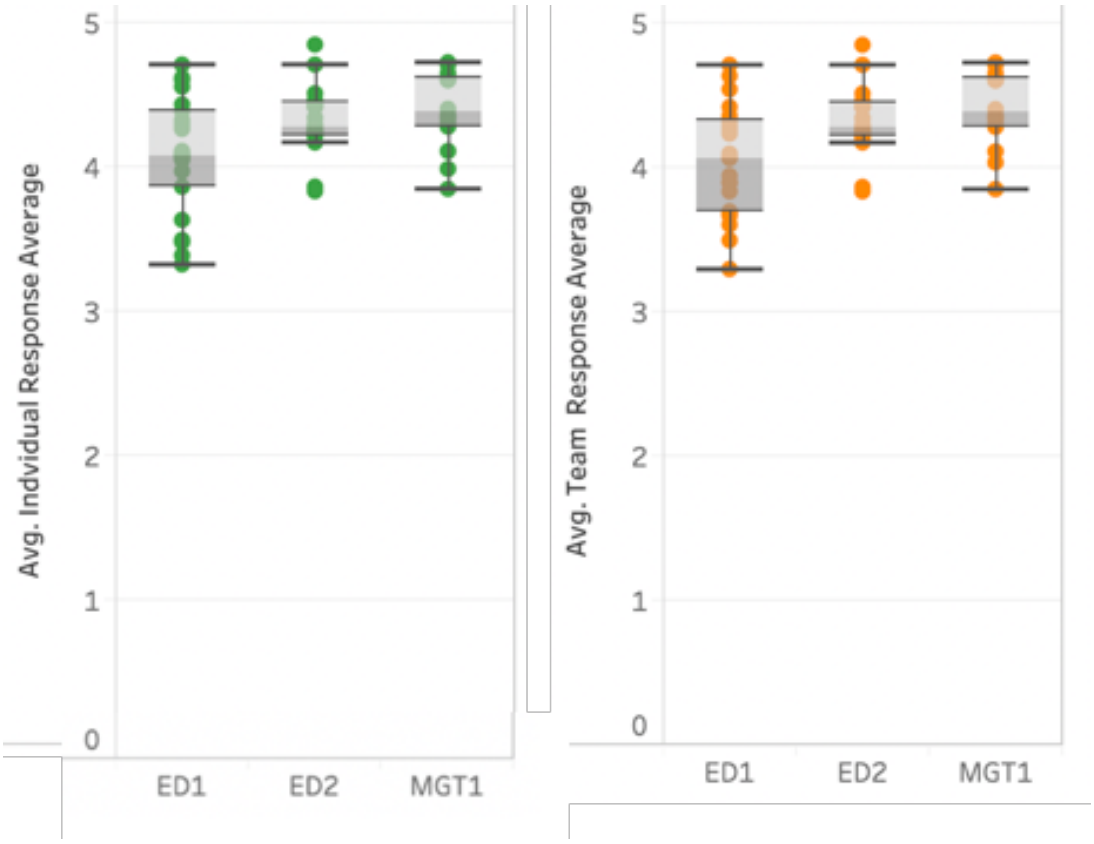


Figure 4. Range of team satisfaction for individuals and teams

Figure 4 shows while the overall average team satisfaction in MGT1, there were several very high team outlier experiences in ED2. The highest team satisfaction was in section I in ED2, with a team satisfaction of 4.86. The lowest team satisfaction score was 3.33 in ED1, section J. MGT1 had the highest average team satisfaction score of 4.41 across all sections.

The team satisfaction scores become more similar in ED2 and MGT1with very low outliers going away in the second-semester course as students become more experienced in working in teams.

Figure 5 shows the survey responses breakdown by the section. We investigated how team satisfaction is distributed based on various sections. The scores are lower for ED1 where the teaming is done by the instructors using the CATME team maker and it is a first teaming experience. The MGT1 individual and team scores are higher than ED1 and ED2 in 8 of the 14 sections. This may be due to the nature of how MGT1 is run with weekly meetings of all adjunct professors, the teamwork experience is much more uniform across all sections or because students are able to make their own teams.

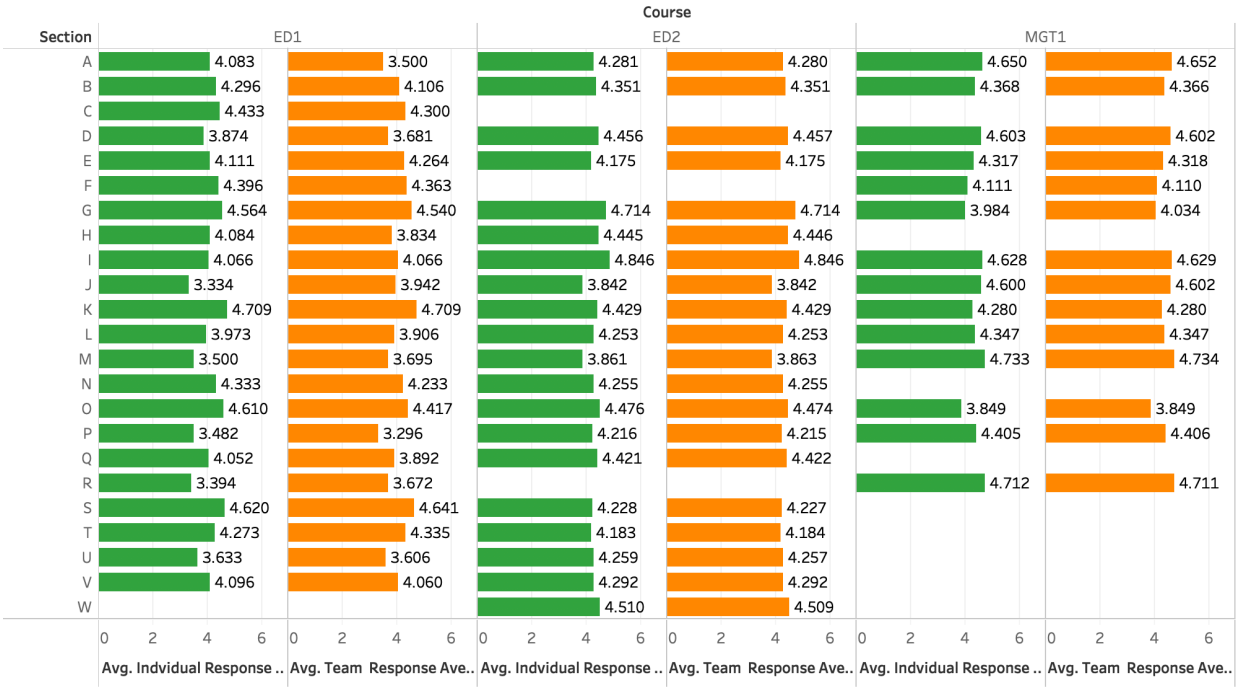


Figure 5. Average and team scores in each section

We analyzed average team satisfaction by instructor to see how the teaming changed from ED1 to ED2 for each instructor. For all but one instructor there was an increase in team satisfaction from ED1 to ED2. One of our new instructors had very small class size and we were unable to use that team satisfaction data (Section C and F). The averages by instructor are presented in Table 1 and Table 2 below.

Table 1: Average team satisfaction by instructor in ED1 and ED2

| Instructor ID (# Sections ED1 / #Sections ED2) | **ED1** | **ED2** | **Change** |
|---|---|---|---|
| IE1 (4 / 1) | 4.27 | 4.89 | 15% |
| IE2 (7 / 7) | 4.09 | 4.24 | 4% |
| IE3 (5 / 4) | 4.07 | 4.24 | 4% |
| IE4 (0 / 2) | | 4.56 | |
| IE5 (3 / 3) | 3.66 | 4.26 | 16% |
| IE6 (1 / 1) | 4.06 | 3.90 | -4% |
| IE7 (0 / 1) | | 4.25 | |
| IE8 (2 / 1) | 4.04 | 4.25 | 5% |
| Average by Instructor | 4.03 | 4.32 | 7% |

Table 2: Average team satisfaction by instructor in MGT1

| Instructor ID (# Sections MGT1) | **MGT1** |
|---|---|
| IM1 (1) | 4.40 |
| IM2 (2) | 4.44 |
| IM3 (2) | 4.55 |
| IM4 (1) | 3.99 |
| IM5 (2) | 4.65 |
| IM6 (2) | 4.59 |
| IM7 (2) | 4.31 |
| IM8 (2) | 4.32 |
| Average by Instructor | 4.41 |

We also analyzed how the personal team experience changed. Table 3 shows how students rated their own personal team satisfaction experience. 73% of students rated their own team satisfaction score in ED2 the same or better than their experience in ED1. 78% of MGT1 students rated their own experience as the same or better than ED2. 87% of students rated MGT1 the same team satisfaction score or a better team satisfaction score for ED1 or ED2.

Table 3: Personal team satisfaction experience

| **Personal team satisfaction experience** | **% of students** |
|---|---|
| ED2 was same or better than ED1 | 73% |
| MGT1 was same or better than ED2 | 78% |
| MGT1 was same or better than ED1 or ED2 | 87% |

Discussion

Our data support our hypothesis that project and team selection have a positive effect on team satisfaction. The MGT1 course had the highest average team satisfaction ratings which may indicate that students enjoy choosing their team and also choosing their projects. This supports the notion that if possible, it is suggested that instructors allow students to form their own teams or select their own projects in courses [9] in the first year.

The presented data supports the notion that working on a team becomes better over time as the first experience had the lowest scores. Both second-semester courses, ED2 and MGT1 scored higher than ED1. This outcome is encouraging, as, like other soft skills, more practice and experience leads to improvements. Team satisfaction did not decrease from ED1 to ED2, eventhough course content became more difficult. The outcomes also support the idea that technically challenging projects can still have positive team satisfaction experiences.

Lastly, there is a bit of fluctuation among sections about teaming which gives some insight to how instructors can play a part in the teaming experiences of the students. The engineering design courses had the same subset of instructors, and 83% had improved team satisfaction in the ED2 course. The average increase by 7% over the second course when compared to the first.

## Concluding Remarks

The course content is fundamentally very different in engineering design courses and a class dedicated to entrepreneurial thinking. This difference can allow students a positive teamwork experience by picking their teams and projects. Many universities are working with the KEEN network to embed modules on the entrepreneurial mindset into existing courses [10,13], and a stand-alone course or a separate project in a non-engineering course can also be beneficial to learn entrepreneurial thinking as well as provide additional opportunities in team work.

In the workforce as in engineering courses, teams are typically assembled based around skillsets that are needed to execute a project. Entrepreneurial thinking and our MGT1 course fall in the innovation and creativity space and can allow for teams to form based on interests and motivation. This result is pretty indicative of the start-up world as well, as passion is the number-one driver to execute on any start-up.

One might wonder how the quality can be maintained in an entrepreneurial project. Small class sizes (less than 28 students), flexible teaching methods, standardized evaluation rubrics, and flipped classroom methods are all used to ensure the learning objectives for these courses are consistently met across the sections. Instructors are able to spend time in the classroom working with teams. Due to the nature of how MGT1 is run with weekly meetings of all adjunct professors, instructors are able to leverage teamwork facilitation experience and training from the course coordinator and from other instructors. The final project for the students in MGT1 is a three-minute explainer video that is published online which is subject to peer review. In the past, some of these videos make it on to kick-starter or Indiegogo which helps ensure quality as well. The course coordinator inspires competition between instructors and gives awards out to the best instructors, which in turns makes the instructors ensure projects are going well. The MGT1 instructors scored only slightly higher on average than the ED2 professors (2%) overall. But for professors that taught both ED1 and ED2, average scores increased by 7%, and all but one instructor had improvement.

## Limitations and Future Work.

Using CATME across multiple courses and sections has been an effective way for us to understand the teamwork dynamic in our first-year experiences. It is unclear exactly what enables the second semester classes to have higher averages than the first semester courses, since all three courses have different subject matter, different styles of projects and different sets of instructors. But an upward trend of better teamwork satisfaction is hopeful. Moving forward we want to try to isolate a few of the sections of ED1 and ED2 and let students choose teams with no restrictions and compare to the other sections. A pilot study in Fall 2019 to Spring 2020 has been planned. Other plans include looking at the effect gender has on teaming as this year we used CATME team maker to ensure woman and underrepresented minorities are not outnumbered on project teams.

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