Exploring Effective Team Formation Strategies for First-Year Engineering Projects

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Abstract

This complete evidence-based paper presents a comparative study on student team formation in a first-year design course at New York University. As the first-year students are not familiar with the concept of group projects, it is of importance to include in the first-year course instruction that those who utilize individual knowledge and strengths in collaborative efforts could potentially achieve greater success than an individual can achieve alone. Team-based exercises are frequently used in educational institutes to promote cooperative and collaborative learning. When it comes to team diversity, a challenging task would be calling for the input and knowledge of people who have distinctive viewpoints and backgrounds to foster insight and innovation. This study used two approaches to investigate the research question: What would be an effective approach to form first-year student project teams with fewer team issues: motivation-driven (self-forming) or background-driven (instructor-led)? In the first approach, called the motivation-driven (MD) approach, students volunteered to promote their project ideas in front of the classroom and invited other students to join the project. In the second approach, called the background-driven (BD) approach, students were asked to put down their first and second preferences for the projects, and the instructor facilitated team formation according to their project preferences, gender, racial, social, and academic backgrounds. Overall, five teams were formed with the MD approach, while 18 teams were formed with the BD approach.
The team dynamics were closely monitored by CATME (Comprehensive Assessment of Team Member Effectiveness) throughout the semester. Students completed peer evaluations at three checkpoints over the semester. The comparative analysis between the two approaches was conducted on the five team dimensions: contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities. According to the CATME peer comments collected over two semesters, the teams formed by both methods received average peer ratings of 4 and above. The study also suggested the project teams formed by the MD approach would generate fewer team issues such as "Manipulator", "Clique" and "Personality Conflict". However, BD approach could offer an alternative route for the class as some students has no initial project ideas. A hybrid team formation strategy was suggested for first-year student project team: the MD approach is first applied in the class, then followed by the BD approach.

Introduction

Teamwork is a common practice for engineering professionals in the form of project teams. The group of individuals known as the "project team" is in charge of carrying out the activities and completing the deliverables specified in the project plan and schedule as instructed by the project manager, at the degree of effort or involvement specified for them [1]. The outcome of a specific project is dependent on the collective individual contributions of every team member. Teams utilizing individual knowledge and strengths in collaborative efforts could achieve greater success than an individual can achieve alone. Team-based exercises are frequently used in educational institutes to promote cooperative and collaborative learning [2-5]. When it comes to

team diversity, a challenging task would be calling for the input and knowledge of people who have distinctive viewpoints and backgrounds to foster insight and innovation [6]. When team members see themselves as similar, they work more effortlessly and easily. In the college environment, diversified team members are from different high schools, regions, and continents — people they know only vaguely or have never met before. Some past studies suggested that the more diverse and unfamiliar the team members were, the less likely team members would work on tasks collaboratively [7, 8].

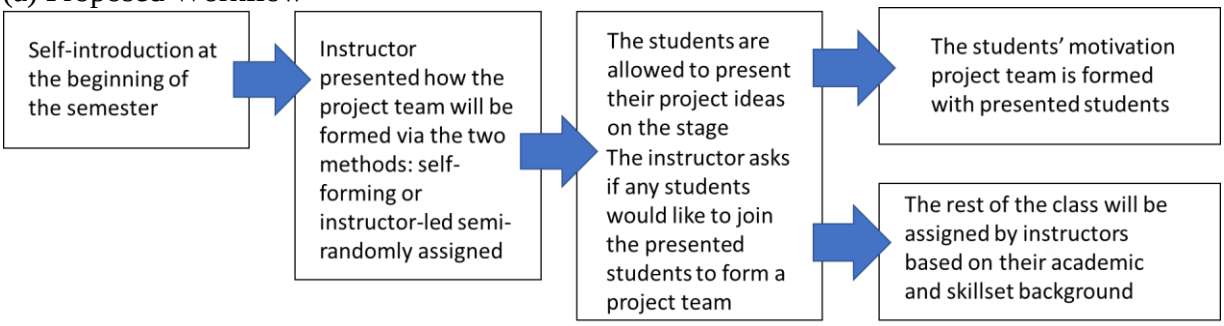
Many researchers have investigated what makes a diverse team successful in the last few decades [9]. One school of thinking is to use effective tools to form teams that could promote collaboration in diverse teams [10, 11]. Researchers have looked at various parameters from the standpoint of how teams should first be created. The team member's personality traits, attitudes and goals, abilities, social preferences, and time availability are among some of the parameters that could be taken into consideration [12, 13]. Automated platforms [14, 15], such as CATME's Team Maker [16], could help instructors form balanced teams and generate optimal team performance via customized survey questions and prioritized team formation criteria. Although the survey questions were comprehensive and exhaustive, the Team-Maker tool has yet to allow students to have the freedom to rank projects they are interested in working on [17]. Some studies observed decreasing sustainable learning motivation and commitment for students if the students are not engaged in the creation of the project questions or activities [18, 19]. This may potentially hinder self-directed learning in project-based courses. This paper explores an alternative way of allowing students to become more engaged in the team formation process. The students would have the opportunity to form teams by themselves and pick the team or project they would like to work on. On the other hand, the conventional students' background information was also used in team formation. CATME peer evaluation would be used to assess the performance of the team from both approaches. A mixed methos approach was used in this study. This aims to further address the following research questions: What would be an effective approach to form first-year student project teams with fewer team issues: motivation-driven (self-forming) or background-driven (instructor-led)?

Methods

Overall Design Approach

Figure 1 shows the overall workflow for the team formation of student project teams. The first step of team formation is students self-introduce themselves in front of the class. The second step is to let the students form a team of three or four by pitching their project ideas. The rest of the class, who chose not to participate in this activity or were not interested in the project ideas, were semi-randomly assigned to form teams according to their background and instructors.

(a) Proposed Workflow



(b) Overall view of the activity within a classroom

Figure 1. The proposed way of forming student teams for semester-long design projects is as follows: (a) Workflow illustrates the breakdown steps that the instructor would follow to form the team in this study, and (b) shows the in-class demonstration.

Motivation-driven Team Formation

The student team was formed by a student pitch. The instructor asked students, "Anyone who would like to pitch their project ideas?" Some students would go up to the stage and present their ideas. For example, Student A could present a project idea about the autonomous delivery robot and ask for two or three team members (a minimum of three students in a team). If two or three students responded "yes" to the pitch, the team was formed, and the project objective was to build an autonomous delivery robot. If more than three students respond to the pitch, the pitching student could ask further questions about their academic background and skillsets and then select the team member based on merits. Therefore, the team was formed as all the team members had a common project goal and strong motivation.

Background-driven Team Formation

The instructor administered a survey and asked about student background, including the following questions: State software or programming languages you have used. What are your goals for this course and your undergraduate degree? What challenges do you face in taking this course? What are the most memorable, exciting, and interesting learning experiences you have? After the MD teams are formed, the instructor will check the team formation sheet (**Table 1**). The rest of the class would follow the BD approach. The instructor would pick the team members according to the survey. The team will be grouped to include a diversity of skills and

academic, cultural, gender, and race background. For example, it would not be advisable to have a team of three all from the same engineering discplines.

Table 1. Team formation sheert used by the instructor (the blue teams highlights MD formation and the orange team highlights BD formation)

(a) Before team formation		
Student names	First preference	Second preference
Student A	N/A	N/A
Student B	RAD	HIR
Student C	HIR	RAD
Student D	HIR	RAD
Student E	RAD	HIR
Student F	RAD	HIR
Student G	HIR	RAD
Student H	HIR	RAD
Student I	HIR	RAD
Student J	N/A	N/A
Student K	N/A	N/A

(b) After team formation			
MRR1	RAD1	HIR1	HIR2
Student A	Student B	Student C	Student G
Student J	Student E	Student D	Student I
Student K	Student F	Student H	

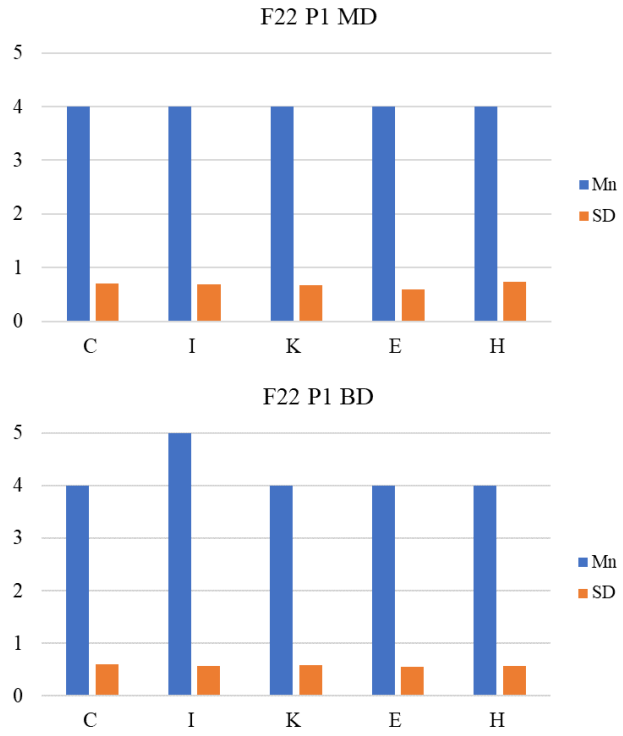
Team Performance Evaluation

The evaluation lasts for two consetive semsters with two different student cohorts. Team performance was assessed via CATME (Comprehensive Assessment for Team Member Effectiveness). There were two peer evaluations throughout each semester. Each peer evaluation covers quantitative peer ratings (incremental scores of 1 — 5) and qualitative peer comments. According to Ohland et al.[20], a fair peer rating is three or above. Therefore, a peer rating of 2 would need the instructor's attention. All the peer comments were thoroughly checked by the instructor, and negative or mediocre comments will be documented for further analysis. The team's academic performance was assessed by the final presentation as well as the submission status of all the project documents to the course instructor.

Results

In the Fall of 2022, 5 of 23 project teams were formed by MD, while the rest of the project teams were formed by BD. **Figure 2** shows the peer ratings from Peer Evaluation I and Peer Evaluation II for the project teams in the Fall of 2022.

Peer Evaluation I (P1)



Peer Evaluation II (P2)

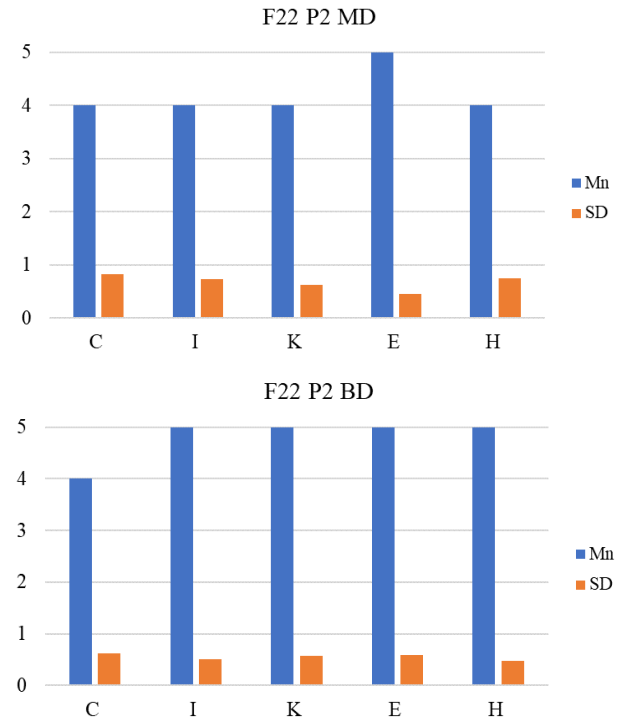


Figure 2. Comparison of peer evaluation between the background-driven (BD) and motivation-driven (MD) teams for the Fall of 2022. “Mn” is the average rating, and “SD” is the standard deviation of peer ratings.

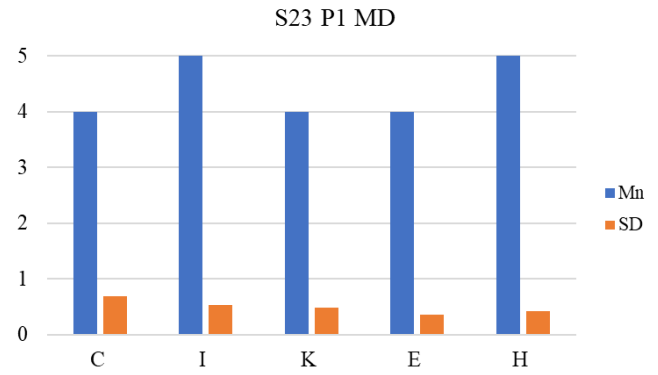
Table 2 shows all the negative comments from project teams in the Fall of 2022, which have been categorized in terms of MD and BD. Overall, CATME was able to identify four notable team issues throughout the semester. Three team issues happened in the BD teams: "Manipulator", "Clique", and "Personality Conflict". One of the students rated themselves 4 or higher while rating all other team members at least two points lower. This triggers the exceptional condition "Manipulator" in the CATME system. Another team issue "Clique" has been notified by CATME as there was widespread disagreement in the rating between various team members. The team had an issue with assigning team roles as they were still exploring project ideas. The last team issue, "Personality Conflict," was reported in Peer Evaluation II. In comparison, there was one team issue being reported in MD teams: "Clique". The team leader, who also advocated the idea during team formation, prefers to work alone and the other two team members have complained about the separation of the group work.

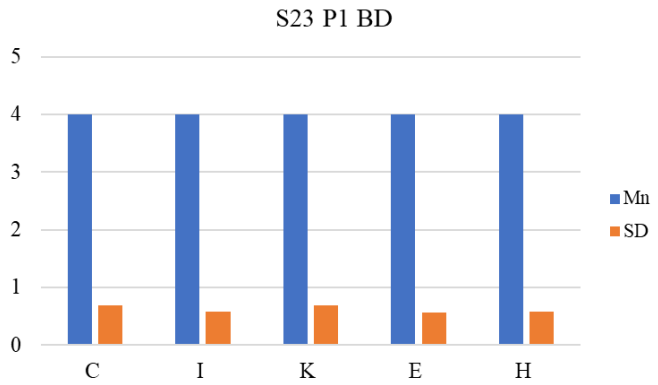
Table 2. Concerned Comments on Team Dynamics in the Fall of 2022	
Peer Evaluation I	
Motivation-driven	**Background-driven**
"I definitely need to find ways to be available more than I currently am. I should make an effort to understand the project goals that are in place because as of right now I'm mostly familiar with the parts I'm working on."	"So far we have had some issues communicating with Student C, and ***I do feel like it is easier to work with Student B than with him.*** Nevertheless, we have continued to include him as normal."
"I believe the team and I should send each other's schedules or let the team know beforehand if they have class during those times or not when we want to meet. Also, it was difficult for me to stay really late with the team to work on the project due to being a Commuter."	"***When she joined the team we were at ground zero and weren't even sure if we wanted to still do RAD or drop out and do HIR.*** When we all agreed to meet that weekend and discuss our decision and work on the Milestone 1 Presentation and Benchmark A, she didn't show up and thirty minutes into the meeting she then tells us she can't make it. We waited an hour in the library and she never showed."
"More than anything, my main concern is that Student A and Student B won't have enough time to get things done for the project with the sports extracurriculars they have."	"Student E, ***I would say that the biggest thing that you may be able to work on is communication.*** There have been times when you missed meetings that Student F and I have held to discuss the project, and as a member of the team, you have every right to provide input on the project and the steps that we need to take…."
Peer Evaluation II	
None	"Therefore, the only possible suggestion would be an increase in an initiative towards starting new tasks or identifying problems independently."

	“Student E consistently appears stressed and tired, which most likely contributes to decreased participation and interest. However, he has recently begun to show a little more interest in the project, so hopefully, that will improve.”

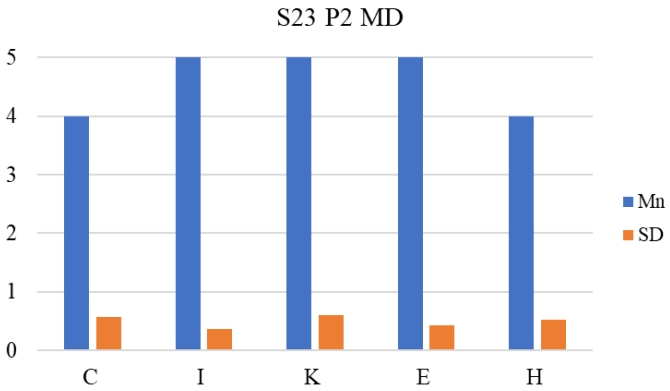
In the Spring of 2023, 8 of 19 project teams were formed by MD, while the rest of the project teams were formed by BD. **Figure 3** shows the team dynamics on Peer Evaluation I and Peer Evaluation II for the project teams in the Spring of 2023.

Peer Evaluation I (P1)





Peer Evaluation II (P2)



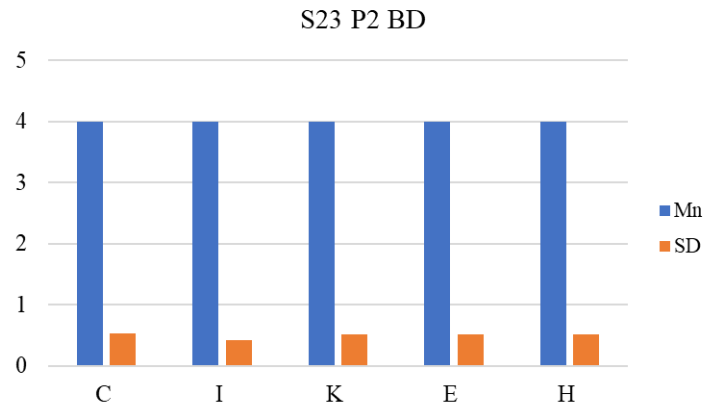


Figure 3. Comparison of peer evaluation between the background-driven (BD) and motivation-driven (MD) teams for the Spring of 2023. "Mn" is the average rating, and "SD" is the standard deviation of peer ratings.

Table 3 shows all the negative comments from project teams, which have been categorized in terms of MD and BD. Overall, CATME was able to identify one notable team issue throughout the semester: "Personality Conflict". The four-student team was formed by the BD approach, and two sub-team groups have formed due to disagreement in engineering design. There was no team issue reported from the MD teams.

Table 3. Concerned Comments on Team Dynamics in the Spring of 2023	
Peer Evaluation I	
Motivation-driven	**Background-driven**
"He communicates about when he can work on the project. On ways to improve, Student G could give more feedback on the designs of other teammates' Revit tasks."	"***I feel that I could take a more proactive role in working on the project instead of waiting for deadlines to come around."***
"In the future, I think it would be beneficial for Student H to stay on top of the requirements, so he is aware of everything that needs to be completed and how. I think more communication would also be very beneficial, and if certain tasks need to be pushed back."	"I'm kind of struggling with time management when it comes to my other classes in addition to my sport. I'm willing to schedule a meeting to help develop a plan and get us on the right path. I'm aware that I am lacking in some areas and will push myself to be more productive."
	"***I am sometimes lost in the project, because of scheduling last minute meetings that I am not available at that time for***. So in the next meeting, I have to catch up to a lot."
	"***Student I has proven to be relatively unreliable.*** She does do her fair share of the work but often puts it off till the same night as the deadline. She also has a tendency to dismiss the importance of the work, by saying things like, ***"I'm definitely going to wait till the night off to do this because there are far***

	more important things to do." She has a knack for not responding to things until after meetings have taken place."
	"***Student J came out this idea, and it was fantastic. However, I did not see Student J puts lots of effort on this project.***"
Peer Evaluation II	
N/A	N/A

Discussion and Conclusion

Peer evaluation results across the two semester provides some insights into team dynamics. In terms of peer ratings in **Figures 2 and 3**, both approaches could form teams that have four and above performance on five dimensions: contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities. According to the rating scale by CATME, this means the team performance was able to demonstrate the following criteria: share the work fairly, communicate well, suggest solutions, want the team to perform well, and demonstrate sufficient knowledge, skills, and abilities to contribute to the team's work [20].

According to the peer comments in **Tables 2 and 3**, the teams that have been formed by BD approaches encountered more task and meeting scheduling issues compared to MD teams. One possible explanation was that some of the students intended to treat the project as only an academic task to complete, place other assignments on priority, and spend the minimum time and effort to work on the projects. On the other hand, the MD teams had clear goals, interests, and motivation from the beginning. The team members were likely to devote more effort to the process. However, the MD team approach would require a leading team member who can carry the entire project to the finish line. As one of the team members described, "I think that this project has been challenging but has been a fun experience so far. I enjoy working on something I haven't worked with before and learning how to work effectively as a group". Therefore, the leading team members were critical in ensuring the project could be commissioned successfully. In the meantime, it is recommended that the instructor assign a TA mentor to the MD team for additional support.

The outcome of this study indicated that both the MD and BD approaches could be potentially used to create sustainable first-year student project teams. The teams formed by both methods have received average peer ratings of 4 and above in the CATME surveys. All the projects have been successfully commissioned. The study also suggested the project teams formed by the MD approach would generate fewer team issues such as "Manipulator", "Clique" and "Personality Conflict". By the definition of CATME, the "Manipulator" is one who rates him as an effective team member while rating others as effective. That contradicts the observation from the rest of the team members. The peer rating of this student could influence the unfair distribution of overall performance. "Clique" means the team will split into a few sub-groups which have no mutual communication. "Personality Conflict" means the student rated another team member at a peer score of 2 while the medium rating of the student from other team members is at a peer

score of 3 or more. Therefore, the students would have certain disagreements happening between the team members. Hence, the MD team formation could possibly generate fewer team issues, as mentioned above. On the other hand, BD approach does provide a good alternative if the students have no initial project ideas or feel less comfortable to do the pitch in front of class.

Overall there are 42 project teams under study from Fall 2022 to Spring 2023. To answer the research question, a hybrid team formation strategy is applicable for first-year student project team: the MD approach is first applied in the class, then followed by the BD approach. The first step in team formation is for students to introduce themselves in front of the class. The instructor would then let the students pitch their project ideas. The project leaders then form groups of three or four based on applicant's academic background and skillsets. The remainder of the class, who chose not to participate in the MD activity or were uninterested in the proposed project ideas, forms their team using BD approach. This means the students are semi-randomly assigned to form teams based on administered class survey. This hybrid approach would serve as a preventative intervention to avoid potential team issues for diverse student teams and can be considered to be used in student projects which lasts for one semesters. On the student side, they would have an agreed project objectives to work together with the MD approach and encountered less team issues with the BD approach.

Acknowledgment

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