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An Experiential Team Formation Process that Leverages Student and Instructor Insights

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Abstract

Team formation sets the foundation for success (or struggle) in capstone design teams. Hence, a significant body of literature has been dedicated to developing best practices in team formation. Researchers have suggested the consideration of more than a dozen different factors including ethnicity, culture, gender, personality, schedule, academic ability, engineering maturity, motivation level, project preference, prior relationships between team members, and team member preference. Additional studies have documented the relative advantages and disadvantages of instructor-based and student-based team selection. Recently, Lane (2011) and Pearlstein (2020) developed and implemented hybrid methods that incorporate both student and instructor perspectives. Both researchers applied their methods to the formation of small (three person) teams of business students who worked on short-term class projects. Their results were promising enough to invite applications in other academic disciplines.

This paper presents an "academic practice / design intervention" that adapts and extends the work of Lane and Pearlstein to engineering capstone design team formation. It adopts their approach of incorporating both student and instructor perspectives in the team formation process. It extends their work by adding an experiential activity that offers insight into potential team dynamics. It also incorporates a reflective exercise that guides students toward more holistic teammate preferences.

The impact of this new team formation method is measured approximately five weeks after project launch when teams have completed their first major project milestone. Results from a CATME peer assessment show significant improvement in team cohesiveness relative to a control group.

Introduction

Embry-Riddle Aeronautical University's Aerospace Engineering program concludes with a major, team-based capstone design project. This two-semester, four course, 11 credit hour sequence includes both engineering and technical communication courses and is co-taught by engineering and communications instructors. Each student invests nearly 500 hours in a team-based project. Each team of six to nine (or more) students completes the design, fabrication and flight testing of an unmanned aerial vehicle. Students document their work through four written reports and eight oral presentations (i.e., design reviews and test readiness reviews). The pace is brisk. The workload is substantial. And, while each team member has a distinct technical role, all work is completed collaboratively. For many students, teamwork is the most challenging element of the project, as documented by Haslam and Beck [1].

An important step in supporting effective teamwork is the use of best practices in team formation. The literature suggests many factors to consider when forming student teams. These factors include ethnicity, culture, and gender [2], [3], personality [4], [5], schedule [3], academic performance [6], engineering maturity (i.e., previous experience in a professional work environment) [7], prior relationships between team members [3], project preference, and team member preference.

In addition to exploring the impact of factors such as diversity and personality on project team performance, the literature also investigates differences between instructor-selected and student-selected teams. Most teams are formed either by the instructor (with little feedback from students) or by the students (with little instructor involvement). The advantages and disadvantages of both methods have been documented [3]. Several researchers have explored the potential advantages of a hybrid approach to team formation that engages both students and instructors in the decision-making process [8], [9], [10]. Lane [9] created and tested a "faux hiring" process to form three-person teams in her Operations Management and Business Plan Entrepreneurship courses. Each student proposed a project idea. Then, the class voted on those ideas. Students with the most popular ideas became team leaders. Next, students interviewed with team leaders, and all students submitted a rank-ordered list of their team preferences to the instructor. Last, the instructor formed teams based on student preferences while also ensuring a "mix of talents." When compared to another class of students who served as a control group, students who participated in the "faux hiring" process reported fewer conflicts and more team cohesion. They also produced significantly better project reports.

Lane's team formation method inspired Pearlstein [10] to undertake a larger study of 399 students in 18 sections of a capstone business course. While his team formation process was similar to Lane's, he chose to use students' past experience as the "control group" against which to compare the new process. Students who participated in the hybrid team formation process reported higher levels of availability, cohesiveness, and team performance relative to their past experiences in student-selected or instructor-selected teams.

Lane's and Pearlstein's studies suggest that student-instructor collaboration in the team formation process yields significant improvements in team cohesiveness and performance. However, for use in engineering capstone courses, some adaptation and extension of their process is necessary.

Many engineering capstone course projects including those at Embry-Riddle Aeronautical University differ in several significant ways from Lane's and Pearlstein's course projects. In specific, engineering capstone course projects:

- Employ teams of 6 to 9+ students (instead of 3 member teams)
- Involve a year-long project (instead of a short-term project)
- Benefit from more intentional selection of the team leader (rather than popular vote)
- Involve more complex projects that require intentional allocation of diverse knowledge and skill sets to ensure that every team has the capacity to succeed

These differences guided the team selection methodologies outlined in the next section.

Methodology

Engineering capstone teams at Embry-Riddle Aeronautical University are usually formed by instructors and informed by students' biographical information. Students complete a survey to provide information on course load, academic achievement (i.e., GPA), skills in design, fabrication, and/or flight testing, leadership experience, professional engineering experience (e.g., internships or research), project preference, and disciplinary interests (i.e., preferred technical role on the team). Students have the option to identify an individual with whom they do not wish to work. Instructors review all survey information, then create heterogeneous teams to equitably distribute knowledge, skills and abilities while also seeking to honor student preferences. Students who express interest in a leadership role are interviewed by the instructors for the role of team lead. This approach to team formation was used for the control group discussed in this paper.

An alternative team formation method, inspired by Lane and Pearlstein, was developed and tested. In this new method, team formation is a collaborative effort between students and instructors. It builds on observations of interpersonal dynamics while still considering individual students' skills and interests. The team formation process is described in the following paragraphs and is used as the experimental group in this paper.

Team formation occurs over the course of two class periods. During the first class, all students engage in two fast-paced, high-stakes group activities. Students are invited to form their own groups. Groups are reformulated between activities. During both group activities, instructors observe interpersonal dynamics. After each group activity, students reflect on their experience. (Details are provided in the appendix.) After completing two group activities and reflections, the instructors facilitate a class discussion of the characteristics of effective team members. The purpose of this discussion is to guide students from their natural preference to group with friends to an appreciation for a heterogenous team of individuals who engage collaboratively. At the end of class, students submit written nominations for team leads.

Between classes, students complete two tasks. First, they complete a biographical survey, as described for the control group, excluding GPA. This is designed to be a streamlined version of a resume that highlights skills and experiences relevant to the course. Next, students review their classmates' surveys, identifying individuals with complementary skill sets and similar project interests with whom they may wish to team.

Between classes, the instructors interview candidates for the role of team lead. Given the scope and challenge of engineering capstone projects, it is not ideal to select team leads based on academic ability. As shown by Steiner [7], high academic achievers often dominate their teams, failing to cultivate interdependence and yielding less effective teamwork. Instead, the best leadership candidates are students who effectively inspire and engage their classmates, as observed by instructors and nominated by peers. After interviewing all leadership candidates, the instructors select one team lead for each project and introduce the team leads at the beginning of the next class.

During the second class, students mingle with prospective teammates. Each team lead hosts a conversation among students with interest in their project. Students are also encouraged to “interview” each other to deepen their insight into prospective teammates’ skills and attitudes. At the end of class, students complete a three-question survey:

1. List top two project preferences (with rationale)
2. Identify top three desired teammates (with rationale)
3. Optionally, list one individual with whom you prefer not to work

After class, the instructors review students’ project and teammate preferences. They also reflect on their own observations of interpersonal dynamics. Then, they select teams with heterogeneous skills, similar project interests, and the potential for positive interpersonal dynamics.

At the beginning of the third class, instructors announce team membership for each project. They also suggest technical roles for each team member. Students engage in ice breaker activities with their new teams, then collaborate to draft a team contract. Both the control and experimental groups participate in this day of activities.

Summary of team formation steps:

1. Students participate in fast-paced, “high” stakes group activities, then reflect on the interpersonal dynamics they experience.
2. Students nominate candidates for team lead (a.k.a., project manager).
3. Instructors interview and select team leads.
4. Students complete biographical information.
5. Students review their peers’ biographical information.
6. Students interview their peers, then rank project preferences and identify preferred teammates.
7. Instructors form teams based on both instructor and student feedback.
8. Teams participate in team-building activities, then draft team contracts.

This new team formation process offers substantial value that potentially translates into more effective, cohesive teams.

- Team leads are selected based on aptitude, not just popularity or interest in the position.
- Students experience interpersonal dynamics with classmates through fast-paced, high-stakes activities before identifying preferred teammates.
- Students reflect on the interpersonal skills that support effective teams.
- Instructors gain perspective on interpersonal dynamics before assigning teams.
- Students reflect on their interests and skills, and how to present themselves in a compelling manner. This prepares them for the university’s Career Expo.

Lane’s and Pearlstein’s research suggests that student-instructor collaboration in the team formation process yields significant improvements in team cohesiveness and performance. To assess whether those benefits extend to the larger teams and more complex projects found in engineering capstone courses, the instructors used CATME's three measures of team cohesiveness. CATME is an acronym for Comprehensive Assessment of Team Member Effectiveness. It is a well-known and widely used web-based tool developed by Ohland, et. al., [11]. Results are compared to a control group (i.e., a prior year cohort) whose teams were formed by the same instructors using traditional factors such as student skills, experience, and project preference.

CATME's three measures of team cohesiveness are task attraction [12], interpersonal cohesiveness [12], and task commitment [13]. Students respond using a Likert scale. Task attraction describes students' enjoyment of the project. Task attraction is assessed using three questions:

1. Being part of the team allows team members to do enjoyable work
2. Team members get to participate in enjoyable activities
3. Team members like the work that the group does

Interpersonal cohesiveness describes students' interactions with teammates. Interpersonal cohesiveness is assessed using three questions:

1. Team members like each other
2. Team members get along well
3. Team members enjoy spending time together

Task commitment describes students' shared level of commitment. Task commitment is assessed using three questions:

1. Our team is united in trying to reach its goals for performance
2. I'm unhappy with my team's level of commitment to the task (scale reversed)
3. Our team members have conflicting aspirations for the team's performance (scale reversed)

Results

Peer assessments are completed several times each semester. The results invite students and instructors to reflect on team dynamics and individual contributions. The subsequent discussions yield rich opportunities for learning and growth. The first peer assessment is conducted approximately five weeks after project launch when teams have completed their first major project milestone. Results for the specific sets of questions relevant to team cohesiveness are shown below in Table 1. The control group includes 23 students, and the experimental group includes 18 students.

Table 1: Measures of Team Cohesiveness

	Control Group		**Experimental Group**	
	Mean	Std. Dev.	Mean	Std. Dev.
Interpersonal Cohesion	3.91	0.51	4.41	0.48
Task Attraction	3.67	0.70	4.19	0.56
Task Commitment	3.86	1.01	4.33	0.38

On average, students in the experimental group reported higher interpersonal cohesion, higher task attraction, and higher task commitment. It was particularly interesting to note that the control group exhibited a large standard deviation in task commitment. In the control group, two of the three teams paired individuals with significantly different levels of commitment to the project. On teams with significantly varying task commitment, students with higher-than-average task commitment were much less satisfied than students with lower-than-average task commitment. In other words, differences in task commitment are more noticeable to highly committed students.

Table 2 evaluates the statistical significance of differences in team cohesiveness. Calculations are based on the means in Table 1. Results suggest that the team formation method outlined in this paper yields more positive interactions with teammates, increased enjoyment of the project, and more homogeneous level of commitment.

Table 2: Statistical Significance of Differences Between the Experimental and Control Groups

	t-value	**Significance**	**Team formation activities yielded:**
Interpersonal Cohesion	3.15	0.0016	More positive interactions with teammates
Task Attraction	2.57	0.0079	Increased enjoyment of the project
Task Commitment	1.90	0.0313	More homogeneous level of commitment

Instructor observations support the quantitative data provided by the CATME peer assessments. In the experimental group, instructors observed far less frustration with differing commitment levels and fewer interpersonal conflicts.

It would be interesting to assess the longer-term impact of team formation process on team cohesiveness. For example, do the benefits of a collaborative, experiential approach to team formation persist for the entire semester or entire year? The instructors were unable to answer that question in the current study. In the control group, team cohesion was so poor that the instructors reformulated teams in the middle of the first semester. This prevented a comparison of the two courses using end-of-semester peer evaluations.

Another interesting question remains unanswered. Lane and Pearlstein observed a statistically significant improvement in academic performance among teams who participated in team formation activities. In the present study, team reformulation and a recalibration of the grading rubric between the control and experimental groups precluded an assessment of the difference in performance between the two groups. In the instructor's experience, interpersonal cohesiveness doesn't automatically imply better performance. Cohesiveness reduces conflict, enabling teams to direct more of their energy toward project goals. However, teams with members who share similar (and apathetic) commitment aren't pushed by those with different aspirations. Further study is needed to understand the benefits (and pitfalls) of team cohesion on performance.

Conclusions

The current study has demonstrated that a collaborative, experiential approach to team formation improves team cohesiveness. In specific, students who participated in activities that helped them understand interpersonal dynamics and identify compatible team members as part of the team formation process enjoyed their work more, experienced more positive interactions with teammates, and benefited from greater compatibility in commitment level.

The method outlined in this paper requires several hours of class time. For semester-long projects, this is a worthwhile investment in setting teams up for success. An abbreviated version of the team formation process may be more appropriate when projects are smaller in scope or duration.

The team formation process outlined in this paper has broad applicability. It is well-suited to any team-based capstone design course. It is also applicable (in a streamlined format) for team-based projects in Intro to Engineering courses and in any other course with a long-term, team-based course activity.

Team experiences can have a positive or negative impact on students' learning. Experience in a poorly functioning team may discourage students from persisting in their chosen major or practicing their chosen profession. In contrast, positive team experiences can provide students with a positive view of working in teams and better equip them for future success in teamwork. When best practices in team formation are employed in lower division courses and/or courses with at-risk students, better retention may be achieved.

Future Work

A natural next step is to expand the team formation process outlined in this paper across multiple instructors' capstone courses to demonstrate repeatability on a larger sample and across instructors. Current work has identified several interesting questions for further study. First, do teams with better cohesiveness achieve better results? Or, can a little discomfort in team cohesion actually challenge and motivate a team to achieve better results? An alternative question to consider is whether teams with better cohesiveness can achieve the same quality of work in less time?

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Day One Activities and Reflection Exercises

Activity 1: Spaghetti Tower
Task: Build a free-standing structure to support three marshmallows
Materials – Every team receives the following material:

- 20 sticks of spaghetti
- 1 yard of tape
- 1 yard of string
- 3 marshmallows

Instructions:

1. Form teams of four
2. Collect materials
3. Build a structure in 15 minutes

Grading Criteria:

- Tower height (taller is better)

Activity 2: Paper Airplane Launcher
Task: Build a paper airplane launcher using a three-step Rube Goldberg machine
Materials:

- Start with the materials that are provided.
- You may include your own materials, if approved in advance by the instructors.

Instructions:

1. Form teams of six (or seven). You must not work with anyone from your Activity #1 team.
2. Take 15 minutes to develop your design. (Your design must include three distinct steps.)
3. Request approval for your design from your instructors.
4. Take 30 minutes to build your Rube Goldberg machine.
5. Take 5 minutes to demonstrate your machine.

Grading Criteria:

- Design creativity
- Flight distance

Reflection (following each activity)
Please answer the following questions with a sentence or phrase.
(Note: This is for you to keep. It will not be shared with your classmates nor graded.)

1. What is one strength of every team member (including yourself)?
2. What is one weakness of every team member (including yourself)?
3. What is one lesson you learned that you can apply in the next activity?