‘Helpful,’ ‘Irritating,’ and ‘Smart’: Student Perspectives on Teams in a Mechanical Engineering Program

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Abstract – An ability to work well in a team is one professional skill employers say is vital to success for recent college graduates. However, while much research has explored aspects of team dynamics, few studies have explored the ways in which students develop interpersonal and teaming skills during their undergraduate career. This paper presents case studies for three students from a twenty-six-student research study. Using qualitative tools such as thematic analysis and text-driven content analysis, each case explores a different issue routinely experienced in undergraduate engineering design teams - diligent isolation, social loafing, and potential gender bias. This research will be of interest to faculty who teach and/or study team communication, especially in engineering programs. A possible application of this research is to design curricular materials that place teaming instruction earlier in a degree program and develop more frequent and effective accountability milestones related to teaming and leadership in capstone courses.

Index Terms – CATME, engineering education, gender bias, teaming.

INTRODUCTION

An ability to work well in a team is one professional skill employers say is vital to success for recent college graduates. The accreditation body for engineering programs, ABET, requires that students possess “an ability to function on multidisciplinary teams” upon earning their degrees [1], usually demonstrated through completion of a Senior Capstone Design (SCD) project. Much research has focused on ways to help students work more effectively in teams through formal instruction such as lectures and assignments related to teaming and informal instruction through coaching. However, few studies have explored the ways in which students develop interpersonal and teaming skills during their undergraduate careers.

In the last several decades, researchers have explored teaming in a wide range of organization types, including corporations [2-3] and undergraduate engineering programs [4-11]. More specifically, factors such as trust [3, 12], social loafing or slacking [7, 10, 13], and peer evaluation [11] have been considered in team performance. Lately, reflection [14-15] has grown more prominent in the literature.

We have learned through experience that the best-functioning SCD teams have produced the best results. However, prior to the implementation of a new undergraduate curriculum in fall 2014 [16], formal instruction in teaming was lacking. This new curriculum includes learning outcomes related to teaming skills, which introduce students to management tools such as team charters and self-reflection exercises in conjunction with team projects. This study tracks the effects of these experiences on twenty-six mechanical engineering students through six required project-oriented courses across six consecutive semesters as they work with people with diverse backgrounds and skill sets on different projects.

This paper presents case studies for three students in the cohort. Each case explores a different issue routinely experienced in undergraduate engineering design teams - diligent isolation, social loafing, and potential gender bias. This research will be of interest to faculty who teach and/or study team communication, especially in engineering programs. A possible application of this research is to design curricular materials that place teaming instruction earlier in a degree program and develop more frequent and effective accountability milestones related to teaming and leadership in capstone courses.

STUDY DESIGN AND METHODOLOGY

In this curriculum, all students are required to complete four Mechanical Engineering Practice (MEP) courses. These courses help students conceptualize and

apply the theory they learn in other courses to a variety of hands-on projects, also known as problem-based or project-based learning [17]. All twenty-six students completed MEP I in fall 2015, MEP II in spring 2016, MEP III in fall 2016, MEP IV in spring 2017, and Senior Capstone Design (SCD) I in fall 2017. At the time of preparing this manuscript, they are enrolled in SCD II during the spring 2018 semester. MEP I and II require students to work in groups in a lab setting, with a different topic covered each week and submit group technical reports. In MEP III, teams work on one simulation project throughout the semester. In the two-semester Senior Capstone Design program, teams of four to six students work with an actual company to develop and prototype a design that meets a set of engineering requirements.

Using the qualitative methods of thematic analysis [18] and text-driven content analysis [19], four types of artifacts were analyzed to explore student views on working in teams as they progress through their BSME degree program. The first set of artifacts is the end-of-semester reflective essays students composed at the end of each of the four aforementioned MEP courses (see [20] for a description of the embedded technical communication content and portfolios in the MEP courses). The second set of artifacts includes the students' self-evaluation of their leadership preferences and the personality traits they seek in teammates. This evaluation is completed at the beginning of the MEP III course. The third set of artifacts includes the CATME (Comprehensive Assessment for Team-Member Effectiveness) [21] peer evaluation ratings and comments completed in MEP III and Senior Capstone Design I and II. Finally, this study also compares the team charters completed in Senior Capstone Design I to the CATME results and reflective essays. (See Wolfe [22] for an excellent description of ways to use team charters in student teams.)

The purpose of these analyses is threefold: 1) Track the ways in which these students develop teaming skills, based on their own comments and assessments by their teammates as they progress through curriculum; 2) Determine what themes emerge from the various artefacts; and 3) Develop methods to improve teaming instruction in the six courses.

CATME FOR TEAM FORMING AND ASSESSMENT

What follows is a brief explanation of CATME tools and their application, which provided valuable data for this study. Two tools within the CATME suite were used. CATME Team-Maker was used to create student teams in MEP III. CATME Peer Evaluation was used in MEP I, MEP III, and SCD to gather peer feedback, which was then used to assign the team contribution portion of student grades.

CATME Team-Maker presents students with an instructor-defined survey of student characteristics (e.g. GPA, Major, Gender, Schedule). After students complete the survey, instructors select the number of members per team and set the optimization direction and strength for each characteristic. There are ten increments between strong diversity and strong similarity. Instructors can also add constraints (e.g. John and Tom must be on separate teams) or manually form complete teams. An optimization algorithm determines a team set that best fits the optimization criteria.

Students in third-year mechanical engineering classes have few criteria by which to diversify. The strategy used in MEP III was to diversify GPA; software, writing, and language skills. Student schedules were given a strong similarity weight to ensure that teams have opportunities to meet and complete assignments outside of class. Another strategy was to form teams of just student-athletes who often have little tolerance for procrastination because of their rigorous training and competition schedules.

In Senior Design, CATME is not used to form teams. Instead, teams are formed based on student interest (ranking their top five choices); qualifications, as determined by student resumes; and diversity considerations (we try to avoid isolating women, minorities, or international students on teams of predominantly white males). CATME is used for peer evaluation, which occurs three times during each semester.

CATME Peer Evaluation presents students with an instructor-defined survey asking for feedback on behaviors of their teammates. The instructor selects focus topics for the survey (e.g. commitment to quality, getting along, meeting deadlines). Rating options have five levels between poor and excellent. CATME compiles the data for each team and assigns two scores for each team member (including self-rating and excluding self-rating). The scores are normalized such that the team average score in unity.

On high-functioning teams, where all team members contribute, individual scores tend to be between 0.98 and 1.02. Standout team members could get higher than a 1.05 rating and poor performers can be less than 0.9. Teams with both high and low performers tend to have a larger range of ratings. In addition to student rating, CAME provides insight into potential team issues. Over-confident and under-confident students are identified when there is a discrepancy between their "with" and "without" self scores. The scores presented in this study are "without" self. CATME will also identify potential clique situations as well as potential manipulators.

Team contribution grades are determined by scaling average team assignment grades by individual without-self ratings. Without-self ratings are used to provide more weight to assessments from teammates. A strong team

member on a strong team will earn a high grade while a low-performing team member on a low-performing team will earn a particularly low grade. This assessment approach is used in MEP I, MEP II, MEP III, SCD I, and SCD II.

COHORT INFORMATION

Before exploring the results of this study, it is important to understand a unique aspect of this particular student population. It is unusual for students to complete all four MEP courses and the two-semester Senior Design sequence in six consecutive semesters. The majority of students spend one or two semesters completing paid co-ops and/or internships at companies, which means there is a break in their coursework. Thus, these 26 students did not take such breaks. This does not mean they did not complete co-ops or internships, which can be done during summer, only that they did not do so during the regular academic year. Anecdotally, the department's advisors indicate that students who strictly follow the course flowchart typically perform above average academically and may be more motivated to perform well in teams, especially when their course grade depends on it. The average GPA of this cohort is 3.21. Just two of the 26 students tended to underperform in comparison with their Senior Design teammates in the four CATME surveys.

One possible indication of these students' performance mindset is their responses two questions in the MEP III CATME survey on leadership preferences. Just six of the students indicated they prefer to follow a leader rather than lead teams themselves, while 12 indicated they preferred to lead and eight felt comfortable leading or following (Table 1). Additionally, 15 students preferred working on teams where leadership is shared equally among all team members, while eight preferred to have one leader who received input from the rest of the team, and three preferred to have one strong leader on a team (Table 2). The question of how the students define leadership is addressed later in this paper.

TABLE 1. PREFERRED LEADERSHIP ROLE.

	Following	**Either following or leading**	**Leading**
Student Responses	6	8	12

TABLE 2. PREFERRED LEADERSHIP STRUCTURE.

	Shared leadership	**One leader w/ input**	**Strong leader**
Student Responses	15	8	3

CASE STUDIES

I. Student profiles

Three students are profiled here to showcase the range of academic ability and demographic of the department's undergraduate program. Student A is a high-achieving white male with a self-reported GPA of 3.97 at the start of his third year and a tendency to be highly critical of his teammates, regardless of their background or ability. He indicated a preference for leading and shared leadership, despite never actually sharing leadership duties with his teammates. In his Senior Design team's charter, he stated a personal goal of relying more on his teammates than he had in the past and asking for help as soon as he recognized the need for it. He also expressed concern about working 12.5 hours a week while carrying a full course load with Senior Design, which is a labor-intensive and time-consuming class despite being worth just two credits.

Student B is also a white male who reported a GPA of 3.0. He indicated he was comfortable being either a leader or a follower and preferred teams in which leadership is shared. He said he valued teamwork as long as "each member pulls their own weight." His only personal goal outlined in the Senior Design team charter was to improve his Computer-Aided Design (CAD) skills.

Student C, a white female with a self-reported GPA of 2.69, also indicated that she was comfortable following as well as leading. However, later in the semester, she described herself as a "natural leader" despite having declined to take leading roles when asked to tackle technical tasks. Her Senior Design team was one of the few that defined specific roles in its charter for each member. Student C's role was "Team Relations Manager - responsible for scheduling the time and place for all team meetings, during meetings directs the team as to the primary goals to be accomplished during the meeting." Her personal goals were to earn a high grade and "actually grasp an understanding of the project," which may indicate a lack of confidence as evidenced later in this analysis.

II. What do students say about their teaming skills, does that perception change over time, and do their teammates share the same perceptions?

Student A first discussed teaming in his MEP II essay when he stated that "the best part of the course was the ability to choose my own teammates. In past classes, I have had very poor teammates, so this semester I made sure I was on a team with people I knew to be hard workers." In his MEP III essay, he acknowledged that he "still struggle[s] with teamwork; I do very well in my classes, and I have a hard time trusting that teammates will live up to my standards. As the work gets more difficult, I am becoming more trusting of my teammates because I genuinely need their help. It's still a work in progress, but it is still progress."

His CATME evaluations in MEP III and Senior Design included detailed accounts of each teammate's contributions or lack thereof on the projects. The word "quality" shows up often in his evaluations as does his struggle to cede control of project work, a trait his teammates often cite, e.g. an MEP III teammate indicated that "[Student A] tried to take control of the group work and doesn't trust others' work." In his first Senior Design evaluation, Student A writes that he has "a tendency to take over projects I'm on, which I've been fighting this semester but has still happened a little. I do well technically and will double-check work to ensure we turn in work that I'm proud to put my name on." Despite these tendencies, his teammates tend to rate him high (1.05 for both evaluations in MEP III and between 1.11 and 1.15 in Senior Design).

Student B states in his MEP III reflective essay that he enjoys "working in teams with different backgrounds and abilities." In his MEP III profile, he also indicates a preference for working in teams where "each member pulls their own weight" because "[i]n previous groups, I end up doing most of the work." He was satisfied with his teammates and their project work in MEP III, stating that "[p]articipation and cooperation among our team is very equal" in the mid-term evaluation and "our team works very well together" in the final evaluation. However, we will see in the next section that one of his teammates had a different perception. He made no comments in his Senior Design evaluations and his teammates did not comment on his performance although his CATME scores ranged from 1.12 to 1.03.

Student C's responses and evaluations were perhaps the most contradictory of the cohort. In her MEP III essay, she states that the MEP courses have helped her "feel more confident and knowledgeable" after "struggling through technical reports, group work, and presentations." As noted earlier, she describes herself as a natural leader but is "also very good with acclimating to a team to help the dynamics of a group become more efficient." Her teammates in MEP III had different perceptions of her contributions and her CATME scores were lower than normal, .89 at the mid-term and .79 for the final evaluation. One teammate indicated that she was "balancing a job with school" and "sometimes struggles conceptually" but "always gives her all and will stick around until the job is done." The other female on the team saw Student C as being "less cooperative" because "she claims to not understand the programs we're working with, which is frustrating because she has been the most successful with in-class demonstrations than the rest of the team. I'm still not sure if this more due to not wanting to take responsibility for a model or because she is under-confident in the programs." This same teammate in the final evaluation continued to notice a lack of confidence in technical abilities, stating she "often backs down from tougher tasks or asks so many questions that someone basically has to walk her through everything step-by-step."

Student C periodically struggled in her Senior Design team, with evaluations ranging from .83 to .95 (in the team's first evaluation one-third of the way into the semester, or week five of fourteen). Based on comments from her male teammates, she and another female self-selected to take charge of documentation rather than more technical roles such as modeling, simulation, and prototyping. This issue will be discussed in the next section.

III. What themes emerge from these artifacts?

The Diligent Isolate - Student A might recognize himself in Pieterse and Thompson's description of a diligent isolate as "an individual who increases his or her effort and willing works alone not only to complete his or her own tasks but also, in an effort to 'save the project', on the tasks of other members" [7]. His style of interaction did not change over the course of his undergraduate career despite recognizing that his need for perfection might be negatively impacting his teammates and the project outcomes. Pieterse and Thompson note "that a diligent isolate in a team more often causes another member to become a social loafer rather than the other way around." While the CATME scores of his Senior Design teammates do not indicate the presence of social loafing, scores have fluctuated during the project. The scores of one initially high-performing female declined by a full point as the project progressed. Student A says of this teammate (Student D) and the other female teammate in the fourth peer evaluation (the first of the second semester), "(they) seem to be mostly along for the ride at this point. They are helping out with communication and planning stuff, but don't seem as competent with the engineering work. I remember (Student D) once saying (mostly serious) that she's not sure why she's in engineering. It's also hard because we can't even really dump much of the documentation off on them because you have to understand it well to be able to document it well. I've been doing most of the nitty-gritty engineering work. Most of this is because that's what I'm comfortable doing and I'm good at it, so I've done it. I'm also the de facto leader of the team." These comments lead to the next theme that emerged - possible gender bias.

Gender Bias - Although Student B believed his MEP III team to be one in which everyone was treated with respect and their ideas valued, the one female member of the team had a very different view. In the mid-term evaluation, she wrote, "I am worried that the only reason why my opinion matters to a few members of the team is because I have been getting grades on the individual parts that are slightly better than that of the team. I am not sure if it is because I have a softer voice, or if it is because I am a girl." Unfortunately, she seems resigned to this

being a permanent condition, stating, "I know that this is something that I am going to constantly work at as an engineer and working in teams." Her opinion changed slightly in the final evaluation, where she indicated, "There was little to no tension in the group. However, some of the major components of the project were discussed by members out of the meeting." This situation left her and another teammate, a white male, feeling shut out from making major contributions.

Another possible instance of gender bias occurred in Student C's Senior Design team, in which she and the other female on the team handled all documentation, including formatting, proofreading, and submitting paperwork to the customer and Canvas, the university's learning management system. Although Student C may not possess strong technical skills, the other female on the team is a strong academic performer, with several successful co-operative and internship employment experiences to her credit. Neither Student C nor her female teammate indicated any concern about the situation. In fact, in her last evaluation, Student C said, "All of the team is on a fairly level playing field for this semester. We all do hard work and pull our weight …"

Meadows and Sekaquaptewa found a tendency for gender-stereotyped roles to emerge in student engineering design teams [23]. However, in-depth interviews would need to be conducted with all of the students on these teams to determine more accurately if, indeed, gender bias was at the root of these situations.

Social loafing, AKA slacking - None of the students profiled here could be considered social loafers. However, they all express concern about the possibility of teammates not "pulling their own weight". In fact, confirming earlier work [7, 9-12], most of the twenty-six students in this study place a high value on equality of effort when evaluating their teammates' performance. While they often state they recognize the value of working in teams as a way to include unique perspectives and talents in solving a problem and as a means of support for each other as they progress through challenging course material, it was that equality of effort that mattered most.

OPPORTUNITIES FOR CURRICULAR CHANGE

These case studies and a review of the responses of the entire cohort of students in this project demonstrate that some of the activities/assignments used are appropriate and should continue to be used, while four opportunities for curricular change in what and how we teach engineering students emerge. First, having students think about their leadership styles, GPA, and team preferences is a valuable exercise, not so much in forming teams, but as a way to encourage reflection. This activity could be strengthened further if students had a better understanding of how leadership is defined and manifests itself. Although leadership is mentioned often as a desirable quality in employees, it is neither defined well nor taught at the undergraduate level in most engineering programs. Additionally, students who express difficulty working in teams early in their academic career often continue to struggle with teamwork. Further coaching in leadership could help those students convert their academic abilities into effective leadership qualities in which they inspire their teammates rather than try to control outcomes.

Second, the CATME peer evaluations provide an excellent way for the students to reflect on their own teaming skills and their colleagues - if they use it. Neither Student B nor his teammates wrote comments in their Senior Design evaluations, missing an opportunity to provide insight into their team processes. While we can guess from his CATME scores that he is doing well, it is just that - a guess. Further strengthening the points value of fully utilizing CATME, i.e. completing the comments sections in addition to assigning scores, would likely encourage students to take advantage of this opportunity for self-reflection.

Third, three technical communication/teamwork modules [20] in the ME Practice III course will be modified to address implicit bias. Additionally, the reflective essay due at the end of the semester will be revised to ask students to reflect on bias issues. This work is a result of the department's participation in the NSF-sponsored Transforming Engineering Culture to Advance Inclusion and Diversity project (Grant No. 1445076), which seeks to empower faculty and staff to improve the social and academic climate for women and underrepresented minorities in mechanical engineering programs.

Finally, while the team charters are an effective way to get students talking about their goals and work style at the beginning of a project, they have little value later in the project unless faculty advisers emphasize the need to revisit the document at key points in the semester to ensure the team follows its own "rules." The caveat is that charters should not become a contract that over-regulates the team at the risk of stifling creativity and productive conflict [12].

FUTURE WORK

These case studies reveal opportunities for further research into team dynamics and interpersonal skill development. A factor analysis of all six Senior Design CATME evaluations could be compared to project outcomes, i.e. was the project deemed successful by the customer and the Senior Design program, could reveal which characteristics play the largest role in team success. Additionally, in-depth in-person interviews with the twenty-six students in this cohort could provide much more context to their team experiences, especially for those students who did not post comments in their peer

evaluations. Additional research is also needed to fully understand the ways in which diligent isolates affect their teammates and determine best practices in coaching such students to be less controlling and more collaborative. Finally, more research into what constitutes gender bias in the eyes of undergraduates and how best to prevent it in undergraduate engineering teams is needed, especially if the field is to reach gender parity.

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