

Fostering Development of Teamwork Skills in an Introductory Engineering Course

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Abstract – Teamwork is cited by educators, employers and professionals as a critical skill for engineering students. Despite increasing usage of teams in engineering courses, rarely is time devoted to formal instruction and assessment of teamwork. Research has shown that to foster development of teamwork skills, activities should be carefully structured with ample opportunities for practice, constructive feedback, monitoring and reflection. This paper describes course activities designed for instruction and assessment of teamwork skills implemented in a first-semester introductory engineering course: a teamwork lecture, team building activities, projects, and informal in-class collaborative activities. To assess student performance, CATME self- and peer-evaluation scores were analyzed. A survey was also provided to students to give insight into perceptions of course activities and learning outcomes. Student performance scores suggest high participation and engagement. Survey results showed student impressions of team activities were positive. 94% felt their teamwork skills had improved as a result of course activities. Open-ended survey questions provided more details into which activities students found most effective and team practices that students felt helped or hindered their success. Results will enhance our understanding of first-year engineering students' perceptions of teamwork and provide guidance in structuring course activities that help students develop teamwork skills.

Keywords—teamwork; engineering; first-year; freshmen; CATME

I. INTRODUCTION

Teamwork, one of the eleven ABET student outcomes in criterion 3, is often cited by educators, employers and professionals as a critical skill for engineering students. Despite increasing usage of teams and collaborative activities in engineering courses, rarely is time devoted to formal instruction and assessment of teamwork. The act of simply putting students into teams is not enough to guarantee learning or development. Research has shown that to foster development of teamwork skills, activities should be carefully structured with ample opportunities for practice, constructive feedback, monitoring and reflection [1].

Cooperative learning has been shown as a way to develop teamwork skills [2]. Cooperative learning is a structured form of group work with five important tenets: mutual interdependence, individual accountability, face-to-face

supportive interaction, guided practice of interpersonal skills, and regular self-assessment of team functioning [3].

Shuman et al. [4] provide examples of effective teamwork instruction. They emphasize the need for high fidelity and complex activities. High fidelity tasks mimic teamwork activities in the workplace and high complexity tasks require greater cognitive effort from the students and interdependence (in other words, could not easily be completed by one or two members).

Oakley et al. [5] provide a comprehensive guide for developing effective teams in college classes based on research in collaborative and cooperative learning. They describe best practices for forming diverse teams, instruction in teamwork, dealing with conflicts, and using peer ratings. The authors describe the benefits of having teams develop an “expectations agreement” in which each team sets their own goals and realistic expectations that they agree to adhere to. This sets a standard and is a way to hold team members accountable. The authors also discuss the effectiveness of peer ratings, not only for assessing student performance, but as a device for helping students develop teamwork skills.

CATME, the Comprehensive Assessment of Team Member Effectiveness (www.catme.org), was developed as a tool for self- and peer-evaluations in team activities [6-7]. The evaluations are anonymous and allow students the opportunity not only to provide feedback to one another and the instructor about team functioning, but also may serve as a learning opportunity for students to think more deeply about team practices and reflect on their own contributions. Additionally, CATME evaluations have been shown as an effective way to assess student learning related to teamwork [8].

In 2016, our university implemented a new two-course sequence for first-year engineering students. These courses were established as part of a common first-year curriculum to introduce students to the profession of engineering and the basic methods and tools necessary for engineering practice. Teamwork instruction was a key focus of these courses. (Additional learning outcomes spanned the areas of critical thinking, written and oral communication, graphics, basic computational and programming skills, ethics and professionalism, design, and project management.) This paper describes activities developed for teamwork instruction and assessment in the first-semester course (*Engineering Methods*,

Tools, and Practice I). Student performance and perceptions regarding the effectiveness of various course activities were assessed. The goal of this work was to assess the effectiveness of course activities and provide insight into first-year engineering students' perceptions of teamwork that could be used to improve teamwork instruction.

II. METHODS

Engineering Methods, Tools, and Practice I (ENGR 110) is a large enrollment course; in Fall 2016, there were approximately 640 students in 18 sections. The course is required for all incoming engineering students in the first semester of their first year and for all students transferring in from other colleges or universities.

A. Instruction and Activities

Students received an introductory lecture for about 30 minutes on effective team practices. Following this lecture, students participated in an icebreaker activity ("Lost at Sea" – students ranked items necessary for survival) to emphasize the value of collaboration over individual work.

Students were placed in teams of 4-5 for the entirety of the semester. Their first activity as a team was to create a team poster; the poster included a team name (selected by the students) and information about each of the team members (e.g. major and things they have in common). The purpose of this activity was for students to learn about one another and enhance team unity. In addition to the poster, teams developed a common expectations agreement [5]. This activity followed the teamwork lecture, so students could think about commitments they would make to their team members to enhance success.

Students participated in three team projects over the course of the semester along with less formal in-class collaborative activities. Projects included research of one of the Engineering Grand Challenges [9], a hands-on study mapping paths on campus with vectors [10], and an engineering ethics case study. Each project was 2-3 weeks in duration and included both in-class and out-of-class student work. Students worked collaboratively with their team members nearly every class period over the semester. Additional activities (unrelated to the team projects) included tasks like think-pair-share of critical thinking concepts or paired problem solving of engineering graphics assignments [11].

B. Assessment

Students completed self- and peer-evaluations of team members using CATME surveys twice (middle and end of semester). Each student rated themselves and team members based on 5 criteria: contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities. Additionally, students answered questions related to their overall team satisfaction. CATME scores for each student were included in their course grade (6%).

To assess student performance related to development of teamwork skills (and whether there were improvements over

the course of the semester), CATME self- and peer-evaluation scores were analyzed. Additionally, an end-of-semester survey was provided to a sample of students (3 of 18 sections in which the author was the instructor) to give insight into student perceptions of course activities and learning outcomes (Table 1).

III. RESULTS

A. CATME evaluations

CATME evaluations were completed for 640 students in the middle of the semester and 638 students at the end of the semester (155 teams). Mean student performance scores (adjustment factor for each student in CATME) were high but decreased slightly from middle to end-of-semester evaluations (not a statistically significant difference) (Table 2). A very small percentage of students received low performance scores (5-6%). Team satisfaction scores were also very high (4.4 on a scale of 1-5) indicating that most students felt their team worked well together.

B. Survey results

86 students completed the end-of semester survey. Results of this survey showed that student impressions of the team activities were overall very positive. 94% felt that their teamwork skills had improved as a result of the activities in ENGR 110 and 87% felt they had learned how to deal with team conflicts. 98% of students had worked in teams prior to this course (in high school or previous college courses) and 100% saw teamwork as a valuable skill for engineers.

Open-ended survey questions provided more details into which activities students found most effective. Question 3 (Table 1) revealed student impressions of course activities. Most students found the longer team projects to be most beneficial (62%), but 17% also cited the shorter in-class graphics activities to be most helpful in learning about teamwork. Other course activities cited by a small number of students as helping their learning included writing team papers (6%), meetings outside of class (5%), team poster (2%), teamwork lecture (1%), and CATME evaluations (1%).

TABLE I. END-OF-SEMESTER SURVEY QUESTIONS

Question	
1	Have you worked in teams in an academic course (high school or college) prior to ENGR 110? (yes/no)
2	How important (not at all, somewhat, a lot) do you think the ability to work effectively in teams is for engineers?
3	Which activities in ENGR 110 helped you the most regarding your learning to work effectively in teams?
4	Think of one activity this semester in which your team worked effectively. What actions by yourself and teammates helped to make this activity successful?
5	Think of one activity this semester in which your team did not work effectively. What actions by yourself or teammates hampered your success as a team?
6	To what degree (not at all, somewhat, a lot) has your ability to work effectively in teams developed through this course?
7	To what degree (not at all, somewhat, a lot) have you learned to deal with team conflicts?
8	What other suggestions do you have for me to improve your learning relating to teamwork?

TABLE II. COMPARISON OF STUDENT CATME RESULTS FROM MIDDLE TO END-OF-SEMESTER EVALUATIONS.

	Middle of semester survey	End of semester survey
Number of students evaluated	640	638
Number of students who completed survey	575	569
Number of teams	155	155
Mean student score (adjustment factor, range 0-1.05)	0.987	0.980
Standard deviation of student score (adjustment factor)	0.110	0.134
Percent of students with score ≥ 0.8	95	94
Mean team satisfaction score (range 1-5)	4.378	4.407
Standard deviation of team satisfaction score	0.835	0.837
Percent of students with team satisfaction score ≥ 4	89	90

Questions 4 and 5 provided insight into how the students defined effective teamwork, asking students about specific team practices that helped or hindered their success. Table 3 shows frequency of responses related to different team practices. Notably, the most frequently cited practice that led to team success was dividing up the work among team members and the most frequently cited practice that hindered team success was unequal participation by group members.

Question 8 asked students for suggestions of changes that could be made to the course to enhance their learning related to teamwork. Most students suggested changes to the projects; 10% thought there should be more hands-on projects and 7% thought the projects should be more difficult (requiring full participation by all team members). 9% simply suggesting adding more team assignments/activities. 8% wanted to switch

TABLE III. THEMES AND FREQUENCY OF RESPONSES TO SURVEY QUESTIONS ABOUT EFFECTIVE/INEFFECTIVE TEAM PRACTICES.

Actions that helped team success		Actions that hampered team success	
Theme	% of Responses	Theme	% of Responses
Equal participation by all team members	14	Unequal participation by team members	23
Divided up work	35	Didn't divide up work evenly	5
Clearly defined goals	1	Unclear goals (confusion about what needed to be done)	12
Timely completion	20	Untimely completion (procrastinated)	14
Good communication	12	Poor communication	10
Good collaboration	23	Did not collaborate	7
Took advantage of individuals' strengths	12	Did not know each other well	5
Had a leader	2	No leader	0
Individual accountability for assigned tasks	12	One or more members did not complete assigned tasks	8
Organized	3	Unorganized	2
Helped each other	6	Didn't help each other	3
Met outside of class	7	Difficulty scheduling out of class meetings	9

teams rather than stay with the same team the whole semester and 7% thought we should use different criteria to assign teams (or let students choose). 6% suggested adding more activities for team bonding/building and 3% thought more time was needed to complete the assignments. 4% of responses were related to the instruction; teaching how to deal with team conflicts or showing real examples of effective teamwork.

IV. DISCUSSION

Generally, student performance (as measured by CATME peer evaluations) indicated that students were engaged with their teams and participation was very high. Student satisfaction with their teams was also very high, suggesting that the method of instructor-formed teams (using the CATME team-maker tool) was effective.

A. Student perceptions of course activities

Responses on the end-of-semester survey indicated that students appreciated the value of developing teamwork skills and most felt that course activities had helped in that regard. In particular, students perceived team projects as the best opportunity to learn about teamwork. This is not surprising as these projects were less structured than in-class activities and required students to plan and think about how to share the workload and meet a common goal. Several students found in-class collaborative activities beneficial; this may be due to the more structured format or the fact that all team members were present and participating. Despite icebreaker and team poster activities (not graded), some students requested more team building activities. This highlights the value students place on knowing and getting along with their team members.

B. Student perceptions of effective teamwork

Perhaps the most interesting results of this study related to the way students defined practices of successful teams. The top issue cited by students for both effective and ineffective teamwork was related to equal participation and the way the work was divided up. It seems that most teams in this course took a "divide and conquer" approach such that they saw importance in planning (dividing up the assignment into individual tasks), and execution by each team member (each person completed their assigned task). With this approach, it was critical that each member participated or else the resulting product was incomplete. Conversely, the second most cited feature of effective teams was that they collaborated or worked together on the assignment. This, along with responses highlighting the importance of meeting and helping one another, show that many students saw the greatest value in their time together. Timely completion was another major issue mentioned by students. This suggests that students perceive completing an assignment in a reasonable amount of time (and by the deadline) as a way to measure team success. Procrastination was something that teams felt hampered their success.

C. Potential for course improvements

With the large number of students, it was difficult to keep up with each team's progress and performance. The CATME

tools helped in this aspect, to get a snapshot of how each team was functioning, and appear to be an effective way of tracking team performance, but there was little feedback in this study related to the effectiveness of CATME. Regarding the teamwork lecture, there was only one related comment in the end-of-semester survey (that it was the most effective course activity for learning teamwork) and several students requested supplementary instruction in dealing with conflicts. Therefore, we will revisit our discussion of handling team conflicts to enhance this portion of the lecture. Though the response to team projects was generally very positive, some students mentioned that projects were too simple, such that not all 4-5 team members were needed (allowing some to slack off). Increasing the complexity of the team projects or clearly defining roles of each team member may help in this regard. There was no mention of the expectations agreement in the survey showing that it had a minimal impact on students. In future semesters, we may have students revisit their agreements after the first team project to see whether they have met their goals and whether they think the agreements should be revised.

There is a second semester course (*Engineering Methods, Tools, and Practice II*) in which students take the tools and skills learned in this course and apply them in a semester-long team design project. A future goal of this work is to evaluate how the teamwork skills learned in the first-semester course transfer and whether student perceptions of teamwork change after a semester-long project.

V. CONCLUSIONS

This paper examined the effectiveness of activities in a first-year introductory engineering course on development of teamwork skills. Generally, students had a positive perception of all activities and the importance of developing teamwork skills. Students cited team projects as the most effective way to develop teamwork skills, though most course activities (teamwork lecture, projects, in-class collaborative activities, development of a team poster, and assessment of team effectiveness using CATME peer evaluations) were cited by some students as beneficial to their learning. Interestingly, a large percentage of students defined team success by the way they divided up the work, whether everyone participated equally, and whether the product was completed in a timely manner. These results enhance our understanding of first-year

engineering students' perceptions of teamwork and will provide guidance in structuring future course activities that help students develop teamwork skills.

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