

Improving Student Perceptions of Teamwork by Scaffolding the Team Project in a First-Year Engineering Course

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Abstract

This Complete Evidence-based Practice paper sought to determine whether scaffolding teamwork in a first-year engineering course project improved student perceptions of teamwork. To address problems of ineffective collaboration and unbalanced distribution of work in teams, the 4-week project was revised to include an individual assignment and structured in-class collaborative assignments prior to the final team-submitted deliverables. Following the project, students completed peer ratings using the Comprehensive Assessment for Team Member Effectiveness (CATME), and results were compared to the peer ratings from the prior year's course which included the same project without the scaffolded assignments. Peer ratings and team satisfaction ratings were significantly higher in 2023 compared to the prior year, indicating improvements in student perceptions of teamwork. Additionally, the number of students with low peer ratings was significantly reduced by nearly 50%, suggesting a reduction in students not participating. These positive findings provide further evidence of scaffolding teamwork to support student learning, particularly in the first year.

Introduction

Teamwork is an important skill for engineering students and is often a key component of first-year engineering courses. 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]. One well-established way to develop teamwork skills is cooperative learning, which is a structured form of group work [2]. Cooperative learning is based on 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]. Oakley et al. [4] 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.

One tool commonly used in engineering education for peer teamwork evaluations is the Comprehensive Assessment of Team Member Effectiveness (CATME) [6, 7]. The CATME evaluation framework is a robust tool designed to assess various dimensions of team members performance within collaborative settings. Students rate themselves and their peers across five dimensions. The first dimension, "Contributing to the Team's Work," assesses the quality and quantity of a team member's output to achieve the overall goals of the team. The second dimension, "Interacting with Teammates," assesses effective communication, constructive feedback, and positive collaboration. "Keeping the Team on Track," the third dimension, evaluates skills in time management, task prioritization, and problem-solving. The fourth

dimension, “Expecting Quality,” gauges a team member’s commitment to motivate the team to produce quality work. Lastly, “Having Relevant Knowledge, Skills, and Abilities,” examines a team member's ability to use skills and previous knowledge to complete required tasks. The CATME tool allows students to apply ratings based on detailed behavior criteria (e.g. “Makes important contributions that improve the team’s work.” or “Misses deadlines. Is late, unprepared, or absent for team meetings.”) and those descriptions are correlated with a numerical scale ranging from one to five, with 1 representing the lowest performance and 5 representing the greatest performance in each area.

Current Study

At the University of Louisville, teamwork is first taught in the first-semester introductory engineering course which also covers critical thinking, professionalism, and ethics. Typically, this course is taught during the Fall semester for all first-year engineering students (nearly 500 students). Teamwork is integrated into the course in two, multi-week team projects throughout the semester. For many years we have followed the recommendations by Oakley et al. [4] regarding team formation, establishing expectations, instruction in teamwork, and use of peer ratings through CATME. However, even with this guidance, some teams struggled to balance the workload amongst group members. For example, some groups have had one or two students write the bulk of the project report. In addition, due to the large enrollment of the course, it was difficult to monitor individual teams’ development and work progression before the final evaluations conducted at the end of the project.

To address these teamwork challenges, in Fall 2023, instructors scaffolded the teamwork assignments in the first team project, with the goal of fostering more effective collaboration within teams. Scaffolding is a well-established instructional technique used to simplify challenging tasks [5]. Weekly assignments were developed to guide students through the project, highlighting opportunities for individual contributions. Additionally, more time in class was dedicated to the project allowing for structured collaboration opportunities. In this way, we sought to improve collaboration within all teams, so that more students would contribute meaningfully to the projects and improve student attitudes regarding teamwork. At the end of the project, students evaluated their teammates using CATME.

The purpose of the current study was to evaluate whether scaffolding the teamwork improved student perceptions of teamwork, specifically in peer ratings of team member performance and overall team satisfaction ratings. Additionally, we sought to determine whether the number of students with meaningful contributions to the team project improved. Outcomes were compared to results from the prior year; in Fall 2022, students completed the same project but without scaffolded teamwork. Our specific research questions were:

1. Did CATME peer ratings improve in the revised course project (2023) compared to the prior year (2022)?
2. Did team satisfaction ratings improve in 2023 compared to 2022?
3. Did the number of students with low participation, as rated by their teammates, decrease in 2023 compared to 2022?

Methods

Participants

Participants included all students enrolled in the first-year engineering course at the University of Louisville in Fall 2022 ($N = 482$) and Fall 2023 ($N = 486$). Not all students completed the CATME evaluation (13% in each year). However, all enrolled students were included in the study as CATME ratings from their teammates were still available.

Description of teamwork assignments

Students were placed into teams of 4-5 members based on responses to the CATME team formation survey. For the first team project, each team chose one of the 14 Engineering Grand Challenges [8] and were tasked with researching the challenge. The purpose of the project was to investigate the societal problem(s) the Challenge seeks to address and to identify recent engineering advances that address their chosen Challenge. Teams were instructed to create a written report and a short (3-4 min) video to share their findings with the rest of the class.

In Fall 2022, the project spanned 4 weeks and had 4 associated assignments (Table 1). All deliverables were team assignments (i.e. 1 per team). The project was introduced in class and teams developed a project management plan. The management plan required teams to plan out their communication (e.g. when would they meet, how would they communicate and share documents), list project tasks (breaking into subtasks), and develop a timeline. The rest of the project was expected to be completed outside of class time. At the end of the second week, an outline was due from the team summarizing their research findings. The project report and video were due at the end of the fourth week.

In Fall 2023, the project also spanned 4 weeks but included 5 assignments (Table 1). The project in Fall 2023 was similar to Fall 2022 in that it started with an introduction in class and development of a project management plan and resulted in a final team report and video due at the end of the 4th week. In the second week, however, students had an individual research assignment, which added an individual accountability component. Specifically, each team member was expected to research their Challenge as well as one recent engineering solution. Then in week 3, teams were given time in class to share their research with their teammates and develop an outline for the report as a team. This added face-to-face supportive interaction. A draft report was due at the end of week 3. In week 4, a second in-class activity had teams evaluate their reports using a critical thinking rubric. In this way, the entire team could discuss the overall report before final submission.

Table 1. Timeline of project-related assignments

	Week 1	Week 2	Week 3	Week 4
Fall 2022	Team Project management plan (in-class)	Team Report Outline (out of class)	No deliverables	Team Final Report and video (out of class)
Fall 2023	Team Project management plan (in-class)	Individual Research (out of class)	Team outline (in-class) Team Draft report (out of class)	Team edit report (in-class) Team Final Report and video (out of class)

Peer Ratings

After completion of the project, students completed (individually) an evaluation for their team members (including themselves) using the CATME peer evaluation tool. Outcomes included:

- Average peer rating for each student in each of the 5 CATME teamwork dimensions (ranged between 1=lowest performance rating and 5=highest performance rating)
 - C – Contributing to the team’s work
 - I – Interacting with teammates
 - K – Keeping the team on track
 - E – Expecting quality
 - H – Having relevant knowledge, skills, and abilities
- Team satisfaction score for each student (“I am satisfied with my present teammates,” ranged from 1=strongly disagree to 5=strongly agree).

Prior to peer evaluation, students were required to complete a practice rating in CATME.

Analysis

To determine whether there were differences in mean peer ratings between the 2 years and assignment modifications, a mixed-design ANOVA was used with CATME dimension (C, I, K, E, H) as a within-subjects factor and year (2022, 2023) as a between-subjects factor. Separately, to determine whether the mean team satisfaction ratings improved, a nonparametric Mann-Whitney U test was conducted comparing distributions of scores across the 2 years. The Mann-Whitney U test was used as data were non-normally distributed.

Additionally, to determine whether the number of students with low participation ratings decreased, chi-square tests were conducted comparing the number of students with low and moderate participation across the 2 years. Students with average peer ratings less than 3.0 (on a 1-5 scale) were categorized as “low participation” and those with average peer ratings less than 4.0 were categorized as “low and moderate participation”.

Statistical analysis was conducted using IBM SPSS Statistics v29. Significance was set at 0.05, but a Bonferroni correction was applied for the exploratory simple main effects analyses.

Results

Peer Ratings

ANOVA results showed a significant main effect of year, $F(1, 966) = 23.77, p < 0.001, \eta_p^2 = 0.024$, with higher peer ratings in 2023 ($M = 4.169, SD = 0.661$) than 2022 ($M = 3.967, SD = 0.756$). Pairwise comparisons showed statistically significant increases ($p < 0.001$) from 2022 to 2023 in all 5 teamwork dimension ratings. As shown in Figure 1 below, means were approximately 0.2 points higher (on a 1 to 5 scale) in 2023 compared to 2022.

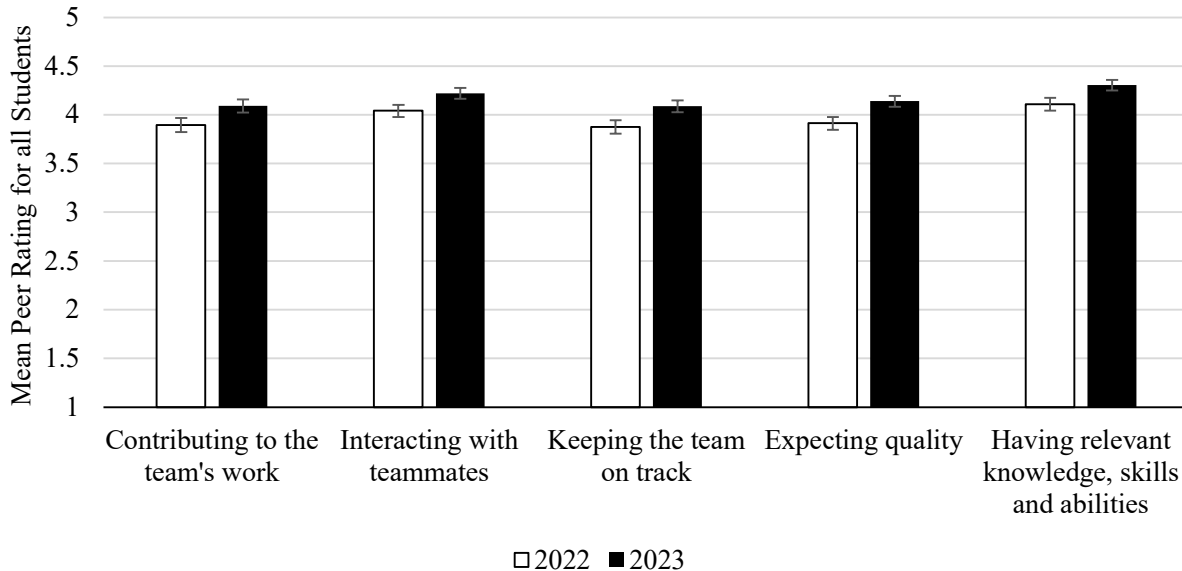


Figure 1. Mean peer ratings for each of the 5 CATME teamwork dimensions in 2022 and 2023. Error bars represent 95% confidence intervals.

ANOVA within-subjects results also showed a significant effect of teamwork dimension ($F(4,3864) = 90.91, p < 0.001, \eta_p^2 = 0.086$), but no significant interaction between the dimension and year factors ($p = 0.57$). Pairwise comparisons revealed that dimension H – Having relevant knowledge, skills and abilities was rated significantly higher than all other teamwork dimensions ($p < 0.001$). Additionally, dimension I – Interacting with teammates was rated significantly higher than remaining dimensions (C, K, E, $p < 0.001$). Dimension K – Keeping the team on track was the lowest rated dimension and was significantly lower than I, E, and H ($p \leq 0.014$).

Team Satisfaction

Team satisfaction ratings also improved from 2022 ($M = 3.584, SD = 1.667$) to 2023 ($M = 3.732, SD = 1.721$). Mann-Whitney U results indicated a statistically significant difference in the distributions ($p = 0.006$).

Participation

The percentage of students with low participation ratings was lower in 2023 than in 2022 (Table 2). The number of students with average CATME peer ratings less than 3.0 (on a 1-5 scale)

decreased from 2022 to 2023 (Pearson chi-square $\chi^2 = 5.162, p = 0.023$). Similarly, the number of students with average CATME peer ratings less than 4.0 (on a 1-5 scale) decreased from 2022 to 2023 (Pearson chi-square $\chi^2 = 21.348, p < 0.001$).

Table 2. Comparison of number of students with low or moderate participation ratings

Year	Number of students with low peer ratings (average rating < 3.0)	Number of students with low and moderate peer ratings (average rating < 4.0)
2022	35 (7.3%)	201 (41.7%)
2023	19 (3.9%)	134 (27.6%)

Discussion

This study sought to evaluate whether scaffolding the teamwork assignments (including individual components and adding in-class time to work as a team) resulted in improvements to student perceptions of teamwork. All measured variables showed improvements with the revised design. In general, students tended to rate their peers higher in 2023 than in 2022 on dimensions of teamwork skills measured in CATME (contributing to the team’s work, etc.). Additionally, the reduction in students with low ratings suggests that the level of participation amongst all team members improved. These results show that the project changes resulted in significant improvements in student perceptions of teamwork.

Two major changes occurred to the team project in 2023. First, an individual assignment was added early in the project so that all team members would be responsible for some of the work. The intent with adding this assignment was to reduce the number of students who made little or no contributions to the team project. In previous years, instructors often saw uneven distributions of effort amongst teams. By adding this assignment early in the project, it was hoped that students would not only contribute to that one assignment, but continue to contribute in later team assignments as they had a foundation of knowledge to add to the final deliverables. The second major change to the project was giving more in-class time for the teams to work on their projects. This change was added to address the challenge of students not finding a time to all meet outside of class. Though class teams were created in part based on common availability, instructors still found that some teams preferred to take a “divide and conquer” approach rather than meet and collaborate. By increasing individual accountability and providing opportunities for substantial collaboration and discussion amongst team members, we aimed to improve team participation, attitudes, and performance. Results indicated that the changes were successful in doing so.

Limitations

This study was quasi-experimental, comparing two different cohorts of students in two different years. Though we assume that student characteristics are generally the same, and the project goals and timeline were similar between the two years, it is possible that other external factors contributed to the differences in teamwork evaluations.

In addition, despite the advantages, CATME has limitations, such as the potential for reduced effectiveness with longer instructions in the rating descriptions, the presence of halo effects in ratings, and biases in peer evaluations. Ohland et al. [6] reported that students stated they were less likely to read longer instructions and conscientiously answer the questions. The presence of the halo effect could also lead to errors in ratings, where students' perceptions of their peers in one area (e.g. personality) affect their impressions in other areas such as teamwork contributions. Students may not have sufficient training to accurately rate peers against the provided criteria. The training exercise does reduce bias, but it is not clear to what degree and whether students utilize that feedback in their actual team evaluations. However, we expect these effects to be similar across years, and therefore the significant differences are still valid.

It is also possible that students modify ratings due to concerns over grades or social interactions, instead of differentiating ratings between different team members. If grades were different across years, this could show altered student responses between the years. Future work could investigate grades as a covariate, or replicate the study with another year of scaffolded teamwork, or perform a controlled experiment to validate results.

Conclusion

This study sought to evaluate whether changes to a team project in a first-year engineering course improved student perceptions of teamwork. The project was revised to include scaffolded teamwork assignments. In particular, an individual assignment was added early in the project and structured collaborative assignments were completed in class. CATME peer ratings and team satisfaction ratings for the project were all significantly higher than those from the prior year. Additionally, the number of students with low peer ratings reduced by nearly 50%, indicating that fewer students did not participate in the project. This study indicates that scaffolding team assignments helps first-year engineering students with teamwork.

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