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# The Influence of Participation in a Multi-Disciplinary Collaborative Service Learning Project on the Effectiveness of Team Members in a 100-level Mechanical Engineering Class

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Prior to joining ODU in 2013, Dr. Ayala spent three years as a Postdoctoral Researcher at the University of Delaware where he expanded his knowledge on simulation of multiphase flows while acquiring skills in high-performance parallel computing and scientific computation. Before that, Dr. Ayala held a faculty position at Universidad de Oriente at Mechanical Engineering Department where he taught and developed graduate and undergraduate courses for a number of subjects such as Fluid Mechanics, Heat Transfer, Thermodynamics, Multiphase Flows, Fluid Mechanics and Hydraulic Machinery, as well as Mechanical Engineering Laboratory courses.

In addition, Dr. Ayala has had the opportunity to work for a number of engineering consulting companies, which have given him an important perspective and exposure to the industry. He has been directly involved in at least 20 different engineering projects related to a wide range of industries from the petroleum and natural gas industry to brewing and newspaper industries. Dr. Ayala has provided service to professional organizations such as ASME. Since 2008 he has been a member of the Committee of Spanish Translation of ASME Codes and the ASME Subcommittee on Piping and Pipelines in Spanish. Under both memberships, the following Codes have been translated: ASME B31.3, ASME B31.8S, ASME B31Q and ASME BPV Sections I.

While maintaining his industrial work active, his research activities have also been very active; Dr. Ayala has published 90 journal and peer-reviewed conference papers. His work has been presented in several international forums in Austria, the USA, Venezuela, Japan, France, Mexico, and Argentina. Dr. Ayala has an average citation per year of all his published work of 44.78.

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**Abstract**
Engineers need to develop professional skills, including the ability to work successfully in teams and to communicate within and outside of their discipline, in addition to required technical skills. A collaborative multi-disciplinary service learning project referred to as Ed+gineering was implemented in a 100-level mechanical engineering course. In this collaboration, mechanical engineering students, primarily in the second semester of their freshman year or first semester of their second year, worked over the course of a semester with education students taking a foundations course to develop and deliver engineering lessons to fourth or fifth graders. Students in comparison engineering classes worked on a team project focused on experimental design for a small satellite system. The purpose of this study was to determine if participating in the Ed+gineering collaboration had a positive effect on teamwork effectiveness and satisfaction when compared to the comparison class. In both team projects, the five dimensions of the Comprehensive Assessment of Team Member Effectiveness (CATME) system were used as a quantitative assessment. The five dimensions of CATME Behaviorally Anchored Ratings Scale (BARS) (contribution to the team's work, interacting with teammates, keeping the team on track, expecting quality, and having relevant Knowledge, Skills, and Abilities - KSAs) were measured. Additionally, within the CATME platform team satisfaction, team interdependence and team cohesiveness were measured. ANCOVA analysis was used to assess the quantitative data from CATME. Preliminary results suggest that students in the treatment classes had higher team member effectiveness and overall satisfaction scores than students in the comparison classes. Qualitative data from reflections written at the completion of the aforementioned projects were used to explore these results.

## Introduction

A summary of reports on engineering curriculum concluded that the undergraduate engineering curriculum lacks rigor in "integrating technical and professional skills through practical experiences" (Szatmary, 2019) even though ABET outcomes address several professional skills. In the current ABET outcomes, outcomes 3 and 5, "the ability to communicate effectively with a range of audiences" and "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives," respectively, address professional skills that involve working with other people (ABET criteria for accrediting engineering programs 2019-2020). While engineering programs have courses in their curricula to address written and oral communication, many engineering students may graduate without being provided the opportunity to communicate to a non-technical audience (Lappalainen, 2009). To improve teaching and learning of professional skills in engineering students, several methods have been investigated, including 1) collaborative learning, 2) interprofessional learning, and 3) service learning. Collaborative learning has been implemented to increase learning of concepts as well as higher order thinking (Menske and Chi, 2019). Interprofessional learning experiences, which involve students in more than one discipline, can expose students to communication with a range of audiences, however there are logistical challenges within interprofessional learning and students may not value the professional skills as deeply as the technical skills (Carrico et al., 2020). Finally, service both in the classroom and at the professional level have increased professional skills without compromising technical skills (Litchfield, et al., 2016), including learning how to communicate effectively with people in different disciplines (Keshwani and Adams, 2017).

Because engineers work with people who have a variety of technical backgrounds, interprofessional communication and collaboration are necessary skills. Typical methods to develop the communication skills of engineers include integrating writing into engineering courses, integrating engineering courses with communication courses, and/or integrating communication across the curriculum (Reave, 2004). However, these methods do not prepare engineers for communicating with people with varied backgrounds. Service learning has been implemented in interprofessional projects where the end recipient of the project is a community in need (Carrico et al., 2020) or students in STEM clubs (Keshwani and Adams, 2017). When engineering students partnered with speech-language pathology students to develop manufacturing processes for in-house fabrication of materials for therapy, there was a clear understanding of the learned technical skills. However, despite the efforts to have students communicate using a commonly used communication tool (slack), the authors found that students did not consistently communicate during the length of the project, they only communicated close to project deadlines. Thus, it was concluded that teamwork skills and communication should be repeatedly emphasized and taught during the course of the project (Carrico et al., 2020). Conversely, in a service learning project involving both engineering and education students implemented in an after-school STEM club, communication and leadership skills in engineering students increased (Keshwani and Adams, 2017), It is possible that the pressure to prepare for an audience of school children forced the college students to put more focus on communicating to their intended audience. Thus, interprofessional service learning successes may be dependent on the end user(s) of the service learning project (the elementary students of the STEM club vs. developing a tool for a speech-language pathologist to use when the patient being helped by the product is not part of the process).

While it is seemingly simple to implement teamwork into a course, team dynamics often result in dissatisfaction because of unequal distribution of workload and poor communication (Ohland et al., 2012). The effectiveness of teams is difficult to measure, but some researchers suggest that self and peer evaluation can teach students to be more effective team members because the act of completing this evaluation causes students to reflect upon their experiences (Ohland et al., 2012). The purpose of this study was to determine if participating in a multi-disciplinary service learning project had a positive effect on teamwork effectiveness and satisfaction when compared to the comparison class. This was evaluated using CATME in both treatment and comparison classes.

**Methods**

Over the course of three semesters from spring 2019 to spring 2020, students in a 100-level course called "Information Literacy in Mechanical and Aerospace Engineering" collaborated with students in a 300-level education class called "Foundations and Introduction to Assessment in Education" to develop and deliver engineering lessons to fourth or fifth graders while on a field trip to the university campus. Team size was dependent on class size, but usually consisted of 5-6 students (2-3 engineering students and 2-3 education students). The teams of students met a minimum of three times outside of class to: 1) complete a team building exercise, including filling out a detailed template for a team charter, 2) draft the lesson plan and prepare for a lesson rehearsal, and 3) reflect on feedback from the rehearsal and finalize the lesson plan. Engineering students enrolled in different sections of the same 100-level engineering class served as comparison classes. These students participated in an engineering design project in groups of 2-3 engineering students during spring 2019 and spring 2020.

Students in the treatment group were provided team Google Sites that included instructions for assignments, a calendar of events, and a document repository with templates for major assignments in a linked Google Drive folder. A team charter was completed during the first meeting, where students defined characteristics of good team members, defined roles and responsibilities, defined ground rules, discussed difficult conversation starters if rules were broken, and signed the charter. Between team meetings 1 and 2, both groups of students worked on different in-class activities to further develop their ideas, and team meeting 2 was dedicated to filling in a template for an engineering lesson plan that included both a lesson plan template and a Google Slideshow template. Prior to the actual lesson with the elementary students the college students rehearsed their lessons with two supervisors, one with an engineering and one with an education background, and another multi-disciplinary student team from their classes. Between the rehearsal and the lesson delivery, students responded to feedback on their lesson delivery, lesson plan, and slideshow and revised their lesson. Finally, students delivered their lesson to fourth or fifth graders during part of a larger field trip to ODU's campus that involved lab tours, dorm tours, and lunch on campus for the elementary students. In spring 2020, instead of a live field trip, the lessons were adapted to interactive Google Slide presentations with embedded audio and video that were distributed virtually to the students who would have come on the field trip.

The comparison group of engineering students were taking the same 100-level class, taught by the same instructor. Students in each comparison group carried out a class project on simplified space systems, where they designed and implemented experiments on earth and identified how these experiments could be conducted in a small satellite. The comparison groups completed an in-class team building activity, where they defined team rules and created difficult conversation starters for when the team guidelines were violated. During the period of performance of the project, at least one class period per week was dedicated to guided activities to help students progress on their project, while the professor was available to give them immediate feedback. Google Sites and document templates were not used for the comparison classes.

**Data collection and analysis**

Students in both the treatment and comparison classes completed an assessment using the Comprehensive Assessment of Team Member Effectiveness (CATME) Behaviorally Anchored Ratings Scale (BARS) instrument (Ohland et. al, 2012) at the end of the project. The CATME BARS assessment evaluates the effectiveness of each team member through a peer and self assessment using a set of 3-8 Likert scale based questions on contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities (KSAs). The Likert scale ranged from 1 to 5, where 1 is "strongly disagree" and 5 is "strongly agree." In addition to BARS, team satisfaction, relationship conflict and team cohesiveness were also assessed in CATME. The team satisfaction score was calculated by answering three questions using a Likert scale: 1) I am satisfied with my present teammates, 2) I am pleased with the way my teammates and I work together, and 3) I am very satisfied with working with this team. Relationship conflict was designed to look at the emotional conflict in a group, and team cohesiveness was designed to help "understand the team's chemistry toward project process and goals" (catme.org). The Likert scale in relationship conflict ranged from 1 to 5, where 1 is "none" or "not at all" and 5 is "very much" or "very often", while team cohesiveness followed the same scale as the other questions. Analysis of Covariance (ANCOVA) was used to test the impact of the Ed+gineering project on five indicators of team effectiveness (contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, having relevant knowledge, skills, and abilities), relationship conflict, and team cohesiveness controlling for team experience. Differences in team satisfaction between treatment and comparison groups were also compared using ANOVA.

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Students in both groups completed a written reflection assignment on the projects. These reflections had similar questions focused on 1) the planning process and teamwork (i.e., team rules, team roles, workload balance, and the overall team experience), 2) information literacy, science, and engineering concepts, and 3) the overall evaluation of the project. These reflections were examined to provide explanations for the differences measured with the CATME data. The themes in relation to the data obtained from CATME are described in Table 1.

| CATME | Key words or phrases |
|---|---|
| Contributing to Team's Work | Fair share, equal work, on time, work balance |
| Interacting with Teammates<br>Cohesiveness<br>Relationship Conflict | Communication – texting/email, zoom<br>Dynamic – got along well (i.e. cohesiveness?) |
| Keeping Team on Track | Leader role, making sure to meet deadlines |
| Expecting Quality | Getting a good grade or doing a good job |
| Having Relevant KSA | Knowledgeable, based on major, etc |
| Satisfaction | Effective teams, positive team experience, benefit |

**Table 1. Key words and phrases used in qualitative analysis used to explain CATME results**

**Results and Discussion**

From spring 2019 to spring 2020, 61 engineering students participated in the treatment group and 49 participated in the comparison group. The sex and race/ethnicity breakdown are shown in Tables 2 and 3. Treatment groups participated in all 3 semesters, while comparison groups were only in spring 2019 and spring 2020.

| **Sex** | **Comparison** | **Treatment** |
|---|---|---|
| Female | 5 | 9 |
| Male | 37 | 47 |
| No answer | 7 | 5 |

**Table 2. Sex distribution of participants**

The CATME BARS assessment and the Team Satisfaction scale showed significant differences between the treatment and comparison groups on the CATME BARS variables *keeping the team on track* ($p$ = 0.05) and *expecting quality* ($p$ = 0.02) (Figure 1). Team satisfaction was significantly greater in the treatment group than in the comparison group ($p$ = 0.027). For all variables examined, there were no differences based on sex, race, or ethnicity.

| Race/Ethnicity | Comparison | Treatment |
|---|---|---|
| Asian or Asian Indian | 4 | 3 |
| Black or African American | 8 | 12 |
| Hispanic, Latino or Spanish | 3 | 1 |
| Native American or Alaskan Native | 0 | 1 |
| Other | 0 | 1 |
| White or Caucasian | 28 | 37 |
| No answer | 6 | 6 |

**Table 3. Race/ethnicity distribution of participants**

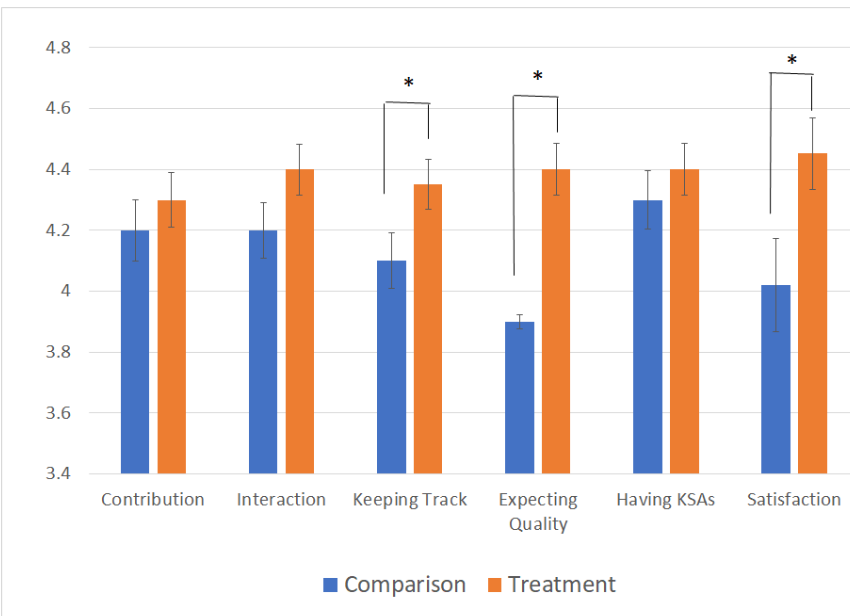


**Figure 1. CATME BARS and *Team Satisfaction* means and standard error comparison showed significant differences between *keeping the team on track* and *expecting quality*.**

Relationship conflict and team cohesiveness data were only collected for two semesters, thus there were 37 participants in the comparison group and 39 in the treatment group. Students reported significantly greater relationship conflict in the comparison group ($p = 0.017$), although the conflict was generally low in both groups. There was significantly more team cohesiveness in the treatment groups ($p = 0.003$) (Figure 2).

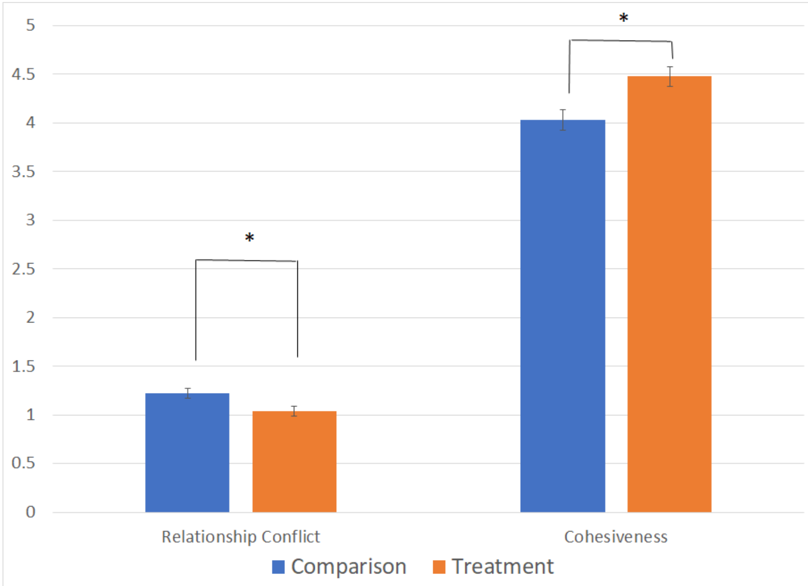


**Figure 2. Relationship conflict and team cohesiveness means and standard error. There were significant differences for both variables.**

There were differences in the assignments to help develop a team's working relationship between the treatment and comparison groups. The treatment group had a detailed team charter to fill out, discuss, and sign as a group. The team charter included identification of characteristics of an effective team member, team member roles and responsibilities, rules for group work that the team agreed on, and creation of difficult conversation starters. The comparison group had an in-class exercise where they defined team rules and created difficult conversation starters that were turned in as a standalone graded assignment. Neither group was asked to review their team charter (treatment) or team rules (comparison) during the course of the semester.

The treatment group also had template assignments to complete that were contained in the Google Site created for each team. The comparison group was given guidelines for assignments and in the spring of 2020, they were provided with a template for their presentation and a data collection documentation to complete. In their reflections, the comparison group did not mention any of the guidelines and templates created for them. Participants in the treatment group were required to use the Google Site and templates for assignments, and generally had positive responses, as indicated with this quote from a student's reflection: "I feel that the team collaboration website was very useful to the team for the project because it put everything we did as a group, or separate, in a common area for anyone to use or reread. Now I will say compared to how we used it before online school was okay due to being able to talk in class, but it was definitely used the most once school was moved to online because we couldn't meet in person."

While team roles were not specified in the results from CATME, the qualitative data suggests that the roles students take on in their groups may be important in shaping team dynamics and student learning skills. Students in the treatment groups from the spring and fall of 2019 split their roles by “knowledge” or “majors,” meaning that students tended to take on roles within their teams that they believed matched their abilities. The comparison group, as well as the spring 2020 treatment group, said that they worked collaboratively on their projects, and that there were no specific roles. For the comparison group, in spring 2019, the instructor advised the students to work together in all phases of the project, and gave class time to design the experiment and analyze their data. In spring 2020, the instructor made specific suggestions on how the team could still work collaboratively after the university went online due to the COVID-19, yet it was noted in both semesters that the person who had the university provided data collection chips did most of the work because students in the comparison group did not collect data in their project before the university closed for the semester. This identifies a limitation of the comparison group, as those students only had one set of hardware per team.

Qualitative data suggested that the treatment group was more satisfied because they were teaching a lesson to students. Also, if the lesson was successful, they were satisfied, despite the performance of their group as one student shared,“Overall I was satisfied with my team experience. I was disappointed with some of my [team] members, but at the end of the day we delivered a great project that I believe will give me a strong grade, which is what matters the most.” While the comparison group had the opportunity to present their project to the company that sponsored their project and be awarded (e.g., most creative project) for their research in the spring of 2020, students in the comparison group did not report any additional motivation because of that opportunity. One student explained this further, "The motivation for me was mostly in knowing I can’t be the one person who lets the project fail as a group. It is a huge responsibility to be accountable and reasonable in a group setting. The mental awareness takes precedence over the possibility of recognition." In the spring of 2020, students in the treatment group did express less satisfaction than prior semesters because they were disappointed that they did not get to interact with the elementary students as they had planned to before university and elementary schools moved classes online. However, the team satisfaction was still greater than the comparison group.

The differences in the team cohesiveness and relationship conflict were harder to explain. Based on the qualitative data, it seemed the teams in the treatment group “clicked” more than the teams in the comparison group. Teams in the treatment group generally reported a positive group connection, as explained by a participant in the treatment group: “Our team was effective and I was very satisfied with my experience overall. I usually am not a fan of teamwork, especially when I don’t know the people I am going to be working with. The people on this team, however, wanted to get a good grade on our assignment and their dedication to the project showed that.” In the comparison group, qualitative data showed that students did not find that connection, but perhaps it was because there was no specific plan for how many times teams should meet outside of class, while the treatment group was told that they had to have three meetings outside of class and the date range in which the meeting should happen. Comparison group reflections similar to this student quote support this assertion, “ The only positive I can think of is this being an example of what not to do when working in a group….The main issue was me and my group mates only really met in class.”

## Conclusion and Future Directions

This study investigated the impact of Ed+gineering, a multi-disciplinary collaborative service learning project, on the effectiveness of team members in an undergraduate engineering course**.** The team satisfaction in the treatment group seemed to be greater than in the comparison group because: 1) the project had more structure (i.e., Google Sites, document templates, required meeting dates, a rehearsal with peer review and outside review, etc.) and 2) the end product of the treatment group was delivering a lesson to elementary students, which provided a high level of positive feedback. More research is planned to examine the impact of the Ed+gineering project on engineering students' teamwork skills and team satisfaction. However initial findings suggest that a multi-disciplinary service learning-based collaboration where teams taught engineering lessons to 4th and 5th graders had a positive influence on students' professional skills, and may be a promising strategy for addressing ABET outcomes 3 and 5, which focus on communicating and collaborating effectively with a range of audiences.

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