# How Does Working on an Interdisciplinary Service-Learning Project vs. a Disciplinary Design Project Affect Peer Evaluators' Teamwork Skills?

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# How does working on an interdisciplinary service-learning project vs. a disciplinary design project affect peer evaluations?

**Abstract**

Over the course of several semesters, two different project-based learning approaches were used in two undergraduate engineering courses–a 100-level introductory course that covered a general education requirement on information literacy and a 300-level fluid mechanics course. One project (treatment) was an interdisciplinary service-learning project, implemented with undergraduate engineering and education students who collaborated to develop and deliver engineering lessons to fourth and fifth-grade students in a field trip model. The other projects (comparison) involved a team-based design project contained within each class. In the 100-level course, students selected their project based on personal interests and followed the engineering design process to develop, test, and redesign a prototype. In the fluid mechanics class, students designed a pumped pipeline system for a hypothetical plant. This study aimed to determine whether participating in the interdisciplinary project affected students' evaluation of their own and their teammates' teamwork effectiveness skills, measured using the Behaviorally Anchored Rating Scale (BARS) version of the Comprehensive Assessment of Team Member Effectiveness (CATME). The five dimensions of CATME measured in this study are (1) contribution to the team's work, (2) interacting with teammates, (3) keeping the team on track, (4) expecting quality, and (5) having relevant knowledge, skills, and abilities (KSAs). The quantitative data from CATME were analyzed using ANCOVA. Furthermore, since data were collected over three semesters and coincided with the pre, during, and post-phases of the COVID-19 pandemic, it was possible to examine the effects of the evolving classroom constraints over the course of the pandemic on the teamwork effectiveness skills of both the treatment and comparison classes.

Preliminary results suggest that students in the treatment classes perceived that their teammates had greater relevant knowledge, skills, and abilities compared to the comparison cohort. Engineering students in the treatment group also believed that their team members were more capable of quality work than the engineering students in the comparison group. Moreover, preliminary results showed a significant drop in scores for expecting quality and having relevant KSA during the peak of COVID during online instruction and performance of both projects, followed by a rise in mean scores during the return to in-person classes. Reflections from available qualitative data were paired to help understand the quantitative data results further.

## Introduction

The increasingly interdisciplinary nature of the modern work environment requires engineering professionals to have the ability to communicate and collaborate with others within and outside disciplinary boundaries [1],[2]. Further, the Accreditation Board for Engineering and Technology (ABET) has long recognized effective communication and teamwork as essential engineering skills, expecting undergraduate engineering programs to support the development of these critical professional competencies [3]. However, undergraduate engineering preparation program coursework experiences often do not mirror these requirements.

Previous efforts to provide interdisciplinary teamwork-based learning experiences in engineering show promising results in fostering cognitive [4] and professional competencies such as communication [5],[6] as educational outcomes. For instance, an interdisciplinary project-based course that partnered computer engineering, marketing, and industrial design students in self-managed teams to build dorm rooms for students with special needs showed positive results in promoting interdisciplinary identities among participants [4]. Keshwani and Adams [6] found that a cross-disciplinary project-based service-learning model teaming engineering and education students had positive effects on participating engineering students' development of communication and leadership skills. Despite the growing literature, research examining whether interdisciplinary project-based learning has the potential to enhance students' development of teamwork skills is still limited [7].

Understanding the benefits of interdisciplinary project-based learning models embedded in undergraduate programs on students' professional skills can inform engineering educators interested in implementing this type of intervention to enhance future engineers' preparation for workplace demands. The present study aims to fill this gap in the literature by first examining whether participating in an interdisciplinary project, which partnered engineering and education students, affected students' evaluation of their own teamwork effectiveness skills and those of their teammates.

The study also explores the effects of the varying intervention modalities due to the COVID-19 pandemic. The quick transition to online learning due to the COVID pandemic affected students and professors across the globe.For example, professors reported having to change their teaching methodologies and strategies to accommodate online learning [8], while other logistical challenges, such as internet access, emerged, affecting both students and instructors [9].Team projects that would otherwise be done in person were deeply affected. Prior studies found that students complained about needing help staying motivated, missing their instructors and peers, and declining hands-on experiences during online learning [10],[11]. However, while some students struggled and others are still struggling and feeling disengaged with the new technology-driven instruction, findings have suggested that some others quickly adjusted to the shift to online learning [12]. Hence, it is relevant to understand how switching from in-person to

online learning affects students' development of teamwork skills traditionally associated with in-person team projects. Therefore, this study focuses on the following research questions.

RQ1: How did participating in an interdisciplinary collaborative service-learning project affect teamwork effectiveness as measured by CATME?

RQ2: How did students perceive the varying intervention modalities during the evolving COVID-19 pandemic affected their teamwork?

## Methods

### Participants

A total of 411 undergraduate engineering students agreed to participate in the research from Spring 2019 to Spring 2022. Out of this, 78.6% of the participating students were male, and 15.8% were female. Most students identified as White or Caucasian (58.9%), followed by Black or African American (16.8%). Participants were assigned to the treatment or comparison group based on the course section they registered for. The treatment group undertook an interdisciplinary project where engineering students partnered with students from a teacher education program, while in the comparison group, engineering students collaborated with their classmates.

### Study Context

For this study, there were two different collaborations that belonged to two different engineering classes - Collaboration 1, a 100-level mechanical engineering class, and Collaboration 3, a 300-level mechanical engineering technology class. All projects were designed to take the same amount of time, with similar scaffolding and challenges. Details of these collaborations are outlined below.

### Comparison Group

Both collaborations had no interdisciplinary projects or service learning for the comparison classes. In Collaboration 1, students in the 100-level engineering class followed the engineering design process to identify a mechanical or aerospace engineering-related problem, brainstorm ideas, create prototypes, test prototypes, redesign prototypes, and re-test the final prototype. For Collaboration 3, students were told that they were a group of engineers working for an Engineering Consulting Firm that had just got a contract with a company to design a new manufacturing facility. The students were given a specific list of tasks to successfully complete the engineering design, such as tank location, flow rate estimate, pipe layout, pump head calculation, and selection, etc. The instructor plays the role of "the client" or "the senior engineer in the consulting firm" and meets with the teams regularly to check on the progress of the project.

**Treatment Group**

The treatment group for both collaborations had engineering students working on interdisciplinary projects with education students to develop and teach engineering lessons to elementary school students. In both collaborations, elementary students traveled to the campus of the university for their engineering lessons.

In Collaboration 1, a 100-level class called information literacy in mechanical and aerospace engineering collaborated with a foundations class in education. The teams in this collaboration were made up of approximately 1⁄2 engineering students and 1⁄2 education students. Both classes were scheduled at the same time so that they could work together during class time to learn the engineering design process in a hands-on activity, test prototypes for the project, and practice their deliverables. Additionally, they were expected to meet at least 3 times outside of class to develop a team charter and develop components of their project. They collaborated to develop and deliver engineering lessons to 4th or 5th graders.

In Collaboration 3, the students needed to pick a fluid mechanics topic, develop a hands-on demonstration activity, and create a lesson plan that an elementary school teacher could use. The engineering students were partnered with elementary pre-service teachers from the College of Education to work on the project.

**Quantitative Analysis**

In the treatment and comparison classes, students used the Behaviorally Anchored Rating Scale version of the Comprehensive Assessment of Team Member Effectiveness (CATME BARS) [13], an alternative to CATME [14], to assess their teammates' teamwork effectiveness skills. To evaluate each teammate, students answered five Likert scale-based questions with responses ranging from 1 to 5, where 1 corresponds to "strongly disagree" and 5 to "strongly agree." The CATME survey assesses five categories of teamwork effectiveness: contribution to the team's work, interaction with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities (KSAs). The project's impact on the team effectiveness indicators based on CATME BARS was evaluated using analysis of covariance (ANCOVA). This analysis compared teamwork effectiveness indexes for comparison and treatment groups controlling for prior teamwork experience. Although engineering students partnered with education students for the treatment groups, only responses for the engineering students were analyzed for this study.

Moreover, since the collaborations and their projects were implemented over several semesters, data was available to explore variations in teamwork effectiveness assessments over different phases of the evolving COVID-19 pandemic. Data from the Spring and Fall 2019 semesters were analyzed together and labeled as the Pre-COVID phase prior to the pandemic. The pandemic evolved in the middle of the Spring 2020 semester; classes started in-person before transitioning

online mid-semester. Hence, Spring 2020 was labeled as a transition period and analyzed independently to understand how students felt about the transition. For Fall 2020 and Spring 2021 semesters, classes were entirely online, and the project ran using a fully online model. Finally, there was a return to in-person classes during the Fall 2021 and Spring 2022 semesters, and with it, the return to the project's in-person activities. Table 1 summarizes how the project was run for both collaborations from Spring 2019 to Spring 2022.

In summary, the data were categorized into different phases based on the COVID pandemic changing the course context and the projects. The phases were Spring and Fall 2019 – Pre-COVID, Spring 2020 – Transition, Fall 2020 and Spring 2021 – COVID/Online, and Fall 2021 and Spring 2022 – Post COVID/Return to in-person. The means and standard deviations for all teamwork effectiveness categories were used to examine the variations in student assessments over the phases mentioned above.

**Table 1. Summary of type of intervention and mode of delivery from Spring 2019 to Spring 2022**

| **Collab** | **Pre-Covid** | | **Transition** | **COVID/Online** | | **Post COVID** | |
|---|---|---|---|---|---|---|---|
| | Spring 2019 | Fall 2019 | Spring 2020 | Fall 2020 | Spring 2021 | Fall 2021 | Spring 2022 |
| **1** | T/F2F<br>C/F2F | T/F2F | T/A<br>C | C/Z | T/Z | C/F2F | T/OffF2F<br>C/F2F |
| **3** | T/F2F | C/F2F | T/A | C/Z | T/Z | C/F2F | T/OffF2F |

**T** = Treatment
**C** = Comparison
**F2F** = On campus face to face implementation
**A** = Asynchronous
**Z** = Zoom
**OffF2F** = Off campus face to face

**Results**

CATME BARS data showed there was a significant difference between the average values of treatment and comparison groups for **Expecting Quality ($p$ = 0.02)** (i.e., members of the team expressing beliefs that the team is capable of excellent work, feeling motivated by the team whiles caring and believing that the team does outstanding work), and **Having Relevant Knowledge, Skills, and Abilities (KSA) ($p$ = 0.01)** (i.e., members of the team knowing what they need to know, being able to perform the role of any team member, acquiring knowledge or skills to help the team and demonstrating skills and abilities to do excellent work). There was no difference between group means regarding contribution to the team's work, interaction with team members, and keeping the team on track (Table 2). Therefore, students in the treatment group were considered to be more knowledgeable, skilled, and capable with reference to the project than the students in the comparison group, and they expected a higher level of quality from the team as well.

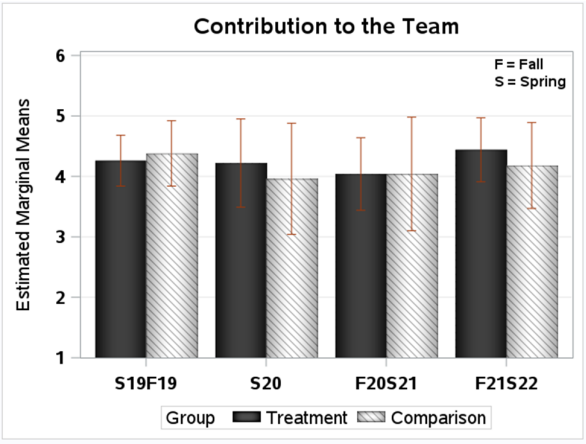
**Table 2. Comparison of the Mean, Standard Deviation, and p-values of the Teamwork categories**

| | Treatment Mean | Comparison Mean | p-value |
|---|---|---|---|
| **Contributing to the Team's Work** | 4.24±0.58 | 4.15±0.79 | 0.21 |
| **Interacting with Teammates** | 4.31±0.51 | 4.28±0.71 | 0.63 |
| **Keeping the Team on Track** | 4.17±0.59 | 4.11±0.79 | 0.36 |
| **Expecting Quality** | 4.25±0.54 | 4.09±0.77 | 0.02* |
| **Having Relevant Knowledge, Skills, and Abilities** | 4.36±0.49 | 4.23±0.76 | 0.01* |

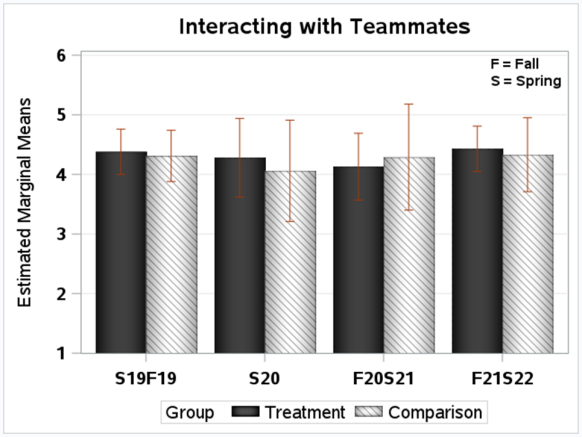
*** = p-value < .05**

While there were no significant differences across the periods of pre-COVID, transition, COVID/online, and post-COVID/return to in-person (Figure 1), the means of all the CATME variables dropped from the pre-COVID semesters to Spring 2020; whereas depending on the variable, the means either increased or decreased again. However, following the return to online learning in Fall 2021 and Spring 2022, teamwork effectiveness skills seemed to have an increasing tendency.

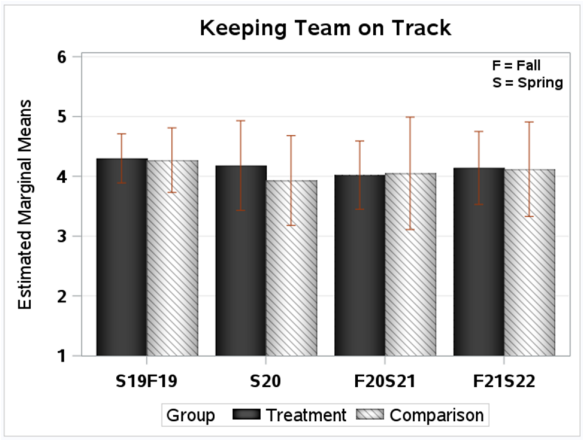
**Figure 1. Plots of Means of the Treatment and Comparison over the several semesters for teamwork effectiveness categories**



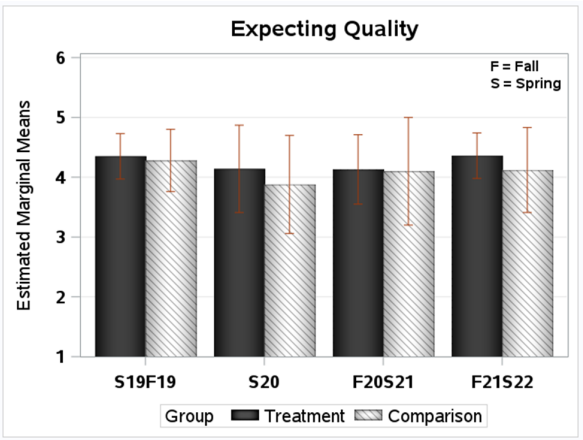

a. Contributing to the team's work



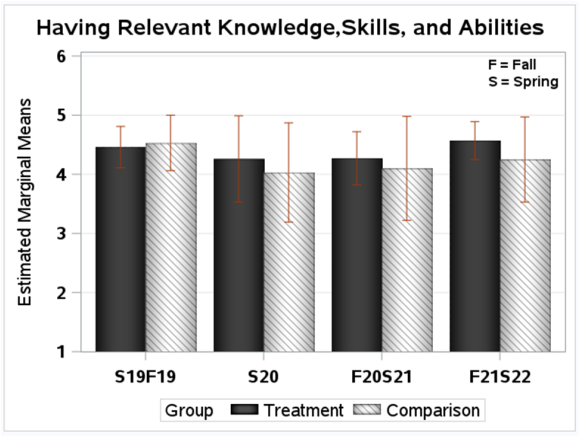

b. Interacting with teammates




c. Keeping the team on track




d. Expecting Quality




e. Having Relevant KSAs

**Figure 1**

Figure 1a. Contributing to the team's work

Figure 1b. Interacting with teammates

Figure 1c. Keeping team on track

Figure 1d. Expecting Quality

Figure 1e. Having Relevant Knowledge, Skills and Abilities.

**Discussion**

The purposes of this paper were: 1) to determine how participating in an interdisciplinary collaborative service-learning project affected teamwork effectiveness and 2) to explore the variations in peer-assessment results due to the evolving classroom constraints triggered by the COVID-19 pandemic.

The results of the present study showed that the interdisciplinary project experience positively affected engineering students' professional competencies in two teamwork effectiveness categories: expecting quality and having the knowledge, skills, and abilities. While CATME is a measure of teamwork effectiveness and not teamwork skills, these results support our hypothesis that these interdisciplinary service-learning projects help develop teamwork effectiveness.

The treatment group's reflections were additionally probed to better understand how the team was effective as they collaborated during the project. Reflection questions, such as were you satisfied with your team experience overall?; what did you learn from working with the education students?; how did moving to a virtual lesson change the way this project affected you?; and how valuable was this Engineering Lessons Project?, were looked into. Responses specifically related to team effectiveness were chosen to support the results from the ANCOVA. From the students' reflections, it was observed that members of the treatment group expressed beliefs that their team could do quality work, felt motivated by members of their team, and cared that the team did outstanding work even if there was no additional reward, supporting the significant results obtained for expecting quality—following quotes from some members of the treatment help illustrate this:

*"I feel like my team was very effective and made the class easier. I benefited from my group a lot during this class because it allowed me to talk about what I learned or wasn't sure about to other engineers. All of my group members were smart guys that really cared about the class which really helped motivate me to be even better. Overall, I was satisfied with my team experience throughout the class, we worked well together and I learned a lot." [Collaboration 3, White male engineering undergraduate]*

*"When preparing for the lesson and giving the lesson to the 4th graders, the team itself was proven effective. We were able to benefit from each other by making sure that we were on top of all things for the project, such as ensuring who gets the supplies and when the deadlines are. We also benefited from having group discussions, which gives us the opportunity to collaborate and share our ideas and work to improve them. Overall, our ability to share and collaborate was a key ideal that we benefitted the most from the team." [Collaboration 1, Black male engineering undergraduate]*

Moreover, from the results, it was portrayed that members of the treatment group knew what to know and what to do to help the project be successful, could perform the roles of other team members when necessary, and demonstrated skills, knowledge, and abilities to do excellent work. This establishes that students in the treatment group had and acquired the relevant knowledge, skills, and abilities to enhance their team's performance when compared with the comparison from the results obtained. The following reflections of some treatment group students support the results.

*"I feel having 2 different majors collaborating on this project was very beneficial to both the education and the engineering students because we were able to bring different perspectives and knowledge to the group. It also allowed us to help and teach each other to new things." [Collaboration 3, Asian female engineering undergraduate]*

*"Working in an interdisciplinary team was an interesting experience. Everyone has different knowledge that they can contribute to the group. There weren't too many difficulties, and I felt like everyone was respectful of each other's academic journey. Learning from each other is definitely a benefit." [Collaboration 3, Hispanic female engineering undergraduate]*

*"I think it was nice working with people from other majors, especially since the project required specialties in both engineering and teaching. It worked pretty seamlessly everybody knew the types of things that they were going to be focused on right off the bat. Honestly, I think it was beneficial because having two Engineers to folks on the engineering things and two education students to focus on delivering that knowledge to the kids and engaging with them worked out really well." [Collaboration 1, White male engineering undergraduate]*

To answer our second research question, Figure 1 shows variations in the students' peer assessment of teamwork effectiveness over the COVID phases. From the plots, student ratings on teamwork effectiveness skills were lower during the transition period, which is spring 2020. Since a considerable amount of the work for the project and planning happened in person and students planned for an in-person event, students had to quickly make changes to their plans as well as getting used to the new online learning.

The following quotes from participating engineering students in the treatment class help illustrate the impacts of the transition period on students and teamwork:

*"Moving to a virtual lesson has dampened the impact the project had on me. I would have learned much more working face-to-face than online. I would have liked talking to the students face to face to see their reaction and hear their ideas." [Collaboration 1, White male engineering undergraduate]*

*"It was most challenging trying to complete the project once we switched to online learning since we had to adjust a lot of our already prepared material." [Collaboration 1, White female engineering undergraduate]*

It was also evident from the comparison classes that students had challenges with the transition from in-person to online classes. The following reflections from the comparison group students shed more light on this.

*"In the beginning before classes went online, I was very vocal about the project and would work with Engineering student to complete assignments on time. After spring break, I became lazy and did not contribute as much as I should have. I would complete most of my assigned work, but I slacked." [Collaboration 1, White female engineering undergraduate]*

*"Before classes moved online, I think my participation was good and declined after classes switched to online. Engineering student was always a good teammate, but Engineering student 2 seemed to always be too busy for the project." [Collaboration 1, White female engineering undergraduate]*

These quotes are consistent with other studies, which reported that some students lost motivation and morale, making the project difficult for them during the transition period from in-person to online studies [15],[16]. Since the project started online and students had already planned and prepared for an in-person activity, it is understandable that the switch would impact students' morale and enthusiasm due to the fact that they had to readjust their project designs and ideas to fit the online environment.

Although both sets of students had challenges during the transition period in Spring 2020, the results indicated that the treatment group persevered more with the impact of the transition affecting the comparison class more.

However, after the transition period, students were still adjusting to working online, hence why the means of teamwork effectiveness skills were slightly higher or lower than in the transition period. For instance, for teamwork effectiveness categories such as Contribution to the team's work, Interacting with teammates, and keeping the team on track, the treatment group had lower means in the online phase than in the transition period. However, the comparison group did better in these categories. These reported declines may be due to the project's interdisciplinary nature for the treatment. Although the COVID pandemic brought many issues, such as morale loss, internal and external communication issues, team management, and many others, to a lot of projects, students in the treatment class experienced these effects more since they were collaborating with students they were not familiar with and also belonged to a different discipline. Most students in the treatment class preferred the project to be in-person, and this was highlighted in the reflections obtained.

"*This experience was valuable to me to get a better grasp at giving better presentations in the future based on knowledge learned here, I think that the online stuff kind of messed it all up but that is a struggle of the time hopefully next semester would be in person and the challenges that brings." [Collaboration 1, White male engineering undergraduate]*

*"We were definitely less prepared because it was online. If we were working in-person, it would have given us more opportunity to get everyone in our group to participate equally. Teaching the lesson in person would also have been much more engaging. In terms of learning, I mainly learned how to properly facilitate a zoom lesson." [Collaboration 1, White male engineering undergraduate]*

*"I think I would have learned more if the lesson was face to face. This is because in the future most meetings will be face to face, however, this project did help me learn how to give an effective presentation online which could be useful in the future." [Collaboration 1, White male engineering undergraduate]*

There was a small improvement in teamwork effectiveness skills in the Fall 21 and Spring 22 semesters when the project returned to in-person (Figure 1). The qualitative data indicated that students preferred the project to be in-person rather than online, which was mildly supported by the increase in means from the previous phase to the final phase considered.

"*The project was extremely valuable, I was able to get hands-on experience working with teaching majors and younger students. I've never taught a lesson plan that I helped design, so it was very rewarding for me." [Collaboration 1, Black male engineering undergraduate]*

**Conclusion**

This paper provides some evidence that an interdisciplinary service-learning model that partnered with engineering students and education students to develop and deliver engineering lessons to elementary school students positively affected engineering students' teamwork competencies. Sufficient evidence was found to indicate that engineering students who were part of interdisciplinary teams received higher ratings in expecting quality and having the relevant knowledge, skills, and abilities. Further data exploration suggests that teamwork evaluations appeared to decline during the transition to an online environment as students had to adapt to virtual collaboration quickly. This suggests that switching to online learning may have affected student teamwork skills.

**Limitations and Future Work**

Students were not randomly assigned to comparison or treatment groups. It was based on their class section and their class time. Moreover, more qualitative data from the comparison group could be obtained for future works to understand the differences between motivation and perceptions from both the disciplinary projects and interdisciplinary projects. Further, reflection assignments could be updated to urge students to reflect more on how the service learning and interdisciplinary components affected their overall performance in the project and the requisite content knowledge that came from the project.

Future studies can examine students' motivations regarding interdisciplinary projects and how they relate to teamwork effectiveness. Future work can also examine the effects of the interdisciplinary project on the students' teamwork effectiveness skills over the course of several semesters.

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**References**

[1]. Lattuca, L. R., Knight, D., & Bergom, I. (2013). Developing a measure of interdisciplinary competence. *The International Journal of Engineering Education*, *29*(3), 726-739.

[2]. Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education*, *109*(3), 508-555. https://doi.org/10.1002/jee.20347

[3]. Accreditation Board for Engineering and Technology. (2021). *2022-2023 Criteria for Accrediting Engineering Programs*. ABET. https://www.abet.org/wp-content/uploads/2022/01/2022-23-EAC-Criteria.pdf

[4]. McNair, L. D., Newswander, C., Boden, D., & Borrego, M. (2011). Student and faculty interdisciplinary identities in self‐managed teams. *Journal of Engineering Education*, *100*(2), 374-396. https://doi.org/10.1002/j.2168-9830.2011.tb00018.x

[5]. Carrico, J., Anjum, J., & Anjum, A. (June, 2020). An Interdisciplinary Project-Based Service Learning and Action Research Project with Mechanical Engineering and Speech-Language

Pathology Students. American Society for Engineering Education (ASEE) 2020 Conference, Virtual. https://peer.asee.org/34137

[6]. Keshwani, J. & Adams, K. (2017). Cross-Disciplinary Service Learning to Enhance Engineering Identity and Improve Communication Skills. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 12*(1), 41-61.

[7]. Lattuca, L. R., Knight, D. B., Ro, H. K., & Novoselich, B. J. (2017). Supporting the development of engineers' interdisciplinary competence. *Journal of Engineering Education*, *106*(1), 71-97. https://doi.org/ https://doi.org/10.1002/jee.20155

[8]. Barr, M., Nabir, S. W., & Somerville, D. (2020, November). Online delivery of intensive software engineering education during the COVID-19 pandemic. In *2020 IEEE 32nd Conference on Software Engineering Education and Training (CSEE&T)* (pp. 1-6). IEEE.

[9]. Asgari, S., Trajkovic, J., Rahmani, M., Zhang, W., Lo, R. C., & Sciortino, A. (2021). An observational study of engineering online education during the COVID-19 pandemic. *Plos one*, *16*(4), e0250041.

[10]. Gutierrez, K. S., Kidd, J. J., Lee, M. J., Pazos, P., Kaipa, K., Ringleb, S. I., & Ayala, O. (2022). Undergraduate Engineering and Education Students Reflect on Teamwork Experiences following Transition to Virtual Instruction caused by COVID-19. *Education Sciences, 12(623*). https://doi.org/10.3390/educsci12090623

[11]. Means, B., & Neisler, J. (2021). Teaching and learning in the time of COVID: The student perspective. *Online Learning*, *25*(1).

[12]. Ramo, N. L., Lin, M. A., Hald, E. S., & Huang-Saad, A. (2021). Synchronous vs. asynchronous vs. blended remote delivery of introduction to biomechanics course. *Biomedical engineering education*, *1*, 61-66.

[13]. Ohland, M. W., Loughry, M. L., Woehr, D. J., Bullard, L. G., Felder, R. M., Finelli, C. J., Layton, R. A., Pomeranz, H. R., & Schmucker, D. G. (2012). The comprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self-and peer evaluation. *Academy of Management Learning & Education, 11*(4), 609-630. doi:10.5465/amle.2010.0177

[14]. Loughry, M. L., Ohland, M. W., & DeWayne Moore, D. (2007). Development of a theory-based assessment of team member effectiveness. *Educational and psychological measurement,67*(3), 505-524. doi:10.1177/0013164406292085

[15]. Wildman, J. L., Nguyen, D. M., Duong, N. S., & Warren, C. (2021). Student teamwork during COVID-19: challenges, changes, and consequences. *Small Group Research*, *52*(2), 119-134.

[16]. Ahmed, S. U., Nguyen-Duc, A., & El-Gazzar, R. (2020, November). IT Students Project Group Work in the Day of COVID-19: Understanding the Impact and Attitudes. In *Norsk IKT-konferanse for forskning og utdanning* (No. 4).