Exploring the Team Dynamics of Undergraduate Engineering Virtual Teams During the Rapid Transition Online Due to COVID-19

Miss Alexis Rae Walsh, University of Tennessee at Knoxville

In May 2021, Alexis completed her fourth year at the University of Tennessee in Knoxville, earning a B.S. in Honors Industrial Engineering with a minor in Reliability & Maintainability Engineering. Beginning in July, Alexis will be starting her career as a Technical Solutions Engineer for Epic Systems.

Ms. Sarah E. Norris, University of Tennessee, Knoxville

I am majoring in Aerospace Engineering with course work in computer science and a minor in entrepreneurship at the Unversity of Tennessee. As a researcher, I am apart of ENLITE Research Group through the university and have an interest in engineering identity development in undergraduate students.

Mr. Nathaniel Blalock, Enlite Research Group Led by Dr. Faber: University of Tennessee - Knoxville

Nathaniel Blalock is pursuing a Chemical Engineering degree with biomolecular and pre-medicine concentrations from the University of Tennessee. He performs engineering education research with Dr. Courtney Faber, metabolic engineering with Dr. Cong Trinh, biotechnology research with Dr. Eric Boder, and neuroscience research with Dr. Larry Millet.

Mr. Daniel Patrick Mountain, University of Tennessee - Knoxville
Dr. Courtney June Faber, University of Tennessee at Knoxville

Courtney is a Research Assistant Professor and Lecturer in the Cook Grand Challenge Engineering Honors Program at the University of Tennessee. She completed her Ph.D. in Engineering & Science Education at Clemson University. Prior to her Ph.D. work, she received her B.S. in Bioengineering at Clemson University and her M.S. in Biomedical Engineering at Cornell University. Courtney's research interests include epistemic cognition in the context of problem solving, and researcher identity.

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Alexis Walsh[a], Sarah Norris[b], Nathaniel Blalock[c], Daniel Mountain[c] and Courtney Faber[d]

a) Department of Industrial and Systems Engineering; b) Department of Mechanical Aerospace Biomedical Engineering; c) Department of Chemical and Biomolecular Engineering; d) Cook Grand Challenge Honors Program
University of Tennessee Knoxville

Introduction

Team projects are common in undergraduate engineering courses and have been shown to improve self-efficacy, communication, and teamwork skills through group discussions and presentations, preparing students for professional engineering practice [1], [2]. Completing projects in a team environment increases effectiveness towards meeting project goals and teaches group members to deal with conflict and delegate to other team members [3]. Navigating team roles and dynamics can be challenging for undergraduate engineering students who have not had instruction on how to solve complex problems as a team [4]. A study led by Laguette identified that informal team leaders make projects more successful by implementing organization, dividing workload, and setting deadlines [5]. Given the importance of the skills developed through team projects and the challenges faced by students working on team projects, it is important that instructors include support and resources within their classrooms.

Virtual team projects have become more prevalent in engineering practice starting in the 1990s with improvement in technology such as the internet and video conferencing [6]. As such, it is important that undergraduate engineering programs prepare students to work with others in an online setting since the prevalence of virtual teams within the workforce continues to grow. Additionally, it has been found that online teamwork can help students work out of their comfort zone, develop group cohesiveness, and better students' negotiation skills [7]. However, there are also various obstacles and challenges students face when working on projects virtually. Wyrick and Cisse found that trust may be more difficult to establish through virtual teams as relationships are not as easily built via technology [8]. To mitigate some of these challenges and establish an effective virtual team, ElSawy and colleagues found that it is important that a team clearly identifies the role of the individuals, goals of the overall team, strategies to achieve the goals, and team leadership [9]. To support the development of trust between team members, they found that scheduled meeting times are essential as they support team building and provide the team time to complete the requirements of the project [9]. Furthermore, first-year undergraduate engineering students who worked on virtual team projects facilitated by an instructor felt they developed an understanding of the engineering design process and skills they could apply to future coursework [1]. Despite the research that has been done, there are limited studies that specifically look at the team dynamics of undergraduate engineering students working on virtual teams and how they change during the transition that students experience when moving from in-person to online teams over a short period of time.

Purpose of Study
The purpose of this study is to investigate how team dynamics in undergraduate engineering project teams changed due to rapidly transitioning to a virtual setting following the beginning of the COVID-19 pandemic. Exploring the challenges and benefits of virtual team projects could provide insight into how to prepare students and educators for future online interactions.

The rapid transition to online instruction provides a unique opportunity to explore the challenges and successes that students had moving from working in-person to on virtual teams. To address these overall goals, we will specifically answer the following research questions:
- How did moving online impact the team dynamic (e.g., changes to communication, challenges for the team, benefits of being online)?
- How did the structure of the teams (e.g., number of students, specific roles identified for team members, connections between team members) impact the online team experience?
- How did the type of meeting environment/structure the teams used impact their dynamics?

To address these research questions, 8 semi-structured interviews were conducted with participants who were recruited from open-ended surveys. Within each interview, questions about team structure, communication approaches, and overall team motivation were asked. Data was analyzed using conventional qualitative content analysis [5], which provides a framework for researchers to construct categories and themes from the data, similar to aspects of grounded theory. We also took a constant comparative approach in our analysis to analyze data across participants and understand factors that may have influenced students' virtual team experiences. Based upon preliminary research, it was expected that team relationship formation, communication, and motivation are factors impacting team dynamics. Understanding the change, either positive or negative, in team dynamics due to transitioning to an online format could be valuable in ensuring the success of online virtual teams. This success is important in preparing students for engineering project teams in their careers.

Positionality
While all authors participated in data collection, the first two authors, Alexis Walsh and Sarah Norris, led the data analysis presented in this paper. Below we include the positionality statements for Alexis and Sarah so that the reader understands the experiences of the lead researchers. Positionality statements, focused on team projects, were written and read by all members of the research team as a means to ensure research quality.

The first researcher listed on this project is Alexis Walsh. She is a senior studying industrial engineering at the University of Tennessee in Knoxville. During the semester the study was conducted, Alexis was also involved in a team project that went online. Her team's struggles with completing their project after it became virtual played a part in her interest to study other students' team dynamics during that spring semester. Alexis' opinions on team projects, recorded prior to data collection for this study, include the importance of communicating often, respecting team meeting times, dividing work as evenly as possible, and having a good relationship with team members.

Sarah Norris, the second researcher in this study, is from Knoxville, TN, where she currently attends school at the University of Tennessee as an undergraduate aerospace engineering student. Like Alexis, Sarah was working on a project team that went virtual in Spring 2020. Prior to data analysis, Sarah stated that within team projects she finds communication, time management, and a functioning final product important to a successful team.

To support research quality, both Alexis and Sarah performed the analysis of the interview data. In addition, throughout the analysis process, Alexis and Sarah shared their findings and preliminary findings with the other members of the research team (i.e., the other three authors on this paper).

Methods
Participants
The participants of this study consisted of undergraduate engineering students at a large research university who were involved in a team project during the transition online during the Spring 2020 semester. From initial surveys, eight students agreed to participate in 30-40 minute interviews inquiring about their specific experiences. These students were recruited to participate in the interviews through an open-ended survey that was sent to all undergraduate engineering students at the university. The survey included questions about the student's major and year at the University as well as open-ended questions that asked specifically about the student's experience on their virtual teams that transitioned online. Four of the interview participants (50%) were first year engineering students at the time of the study. There were also one second year, two third years, and one fourth year undergraduates.

Data Collection
A standard interview protocol was developed and prior to each interview, we used the participant's survey data to update general questions and add any other questions needed to further understand the student's experience. The interview questions were organized into five categories to gain an understanding of the project, the team structure, project management approaches used, challenges faced, and the participant's general online experience. Together, Alexis and Sarah conducted the interviews via Zoom, splitting the questions up and asking clarifying questions as needed. The interviews were recorded and only the audio recording was saved under the participants' pseudonyms. The interviews were transcribed by the first three authors and checked for accuracy prior to analysis.

Data Analysis
Data were analyzed using a conventional content analysis approach with no preconceived notions [10]. Because of this, no pre-existing work related to the research question was consulted to inform the initial development of codes. After interviews were read through at least once by Sarah and Alexis, the interviews were read through again with the particular research questions in mind. Sarah and Alexis separately highlighted phrases from the transcripts that related to the research questions and jotted down loose code ideas affiliated with the phrase. They repeated this process for each participant, resulting in the development of an initial codebook. The codebook included the code names and definitions. Using the developing codebook, Sarah and Alexis read through each participant's interview looking for examples, counterexamples, and similarities of the created codes.

In order to refine and more clearly define the codes and test the reliability of the created codebook, Inter-Rater Reliability (IRR) was used to quantify code clarity across researchers [11]. Alexis and Sarah worked to evaluate IRR for the team dynamics codebook, as these were the key researchers focused on research questions regarding team dynamics. Each team member would read through 2 interviews in Microsoft Word Document format, individually identifying via comments where the defined codes could be seen. A macro used to extract both researcher's comments out of the Word Document transcripts was run. The macro produced a table of extracted comments, including what comment was made (code name), what text was commented (code example), and which researcher made the comment (Alexis or Sarah). IRR was calculated for each transcript based on the number of times both researchers commented the same codes using the equation

$$IRR \ = \ \frac{number\ of\ times\ the\ same\ code\ was\ commented}{total\ number\ of\ different\ codes\ commented}.$$

The number of codes that one researcher had that matched the other was divided by their total number of comments, and this was done with respect for both researchers. The IRR would possibly yield different results when done with respect to each researcher if one researcher associated two codes to the same quote. If IRR was less than 80%, the discrepancies were discussed and the code definitions were refined to clarify the codes and level the two researchers' understanding of that code definition. This process was repeated with two more transcripts at a time for as many times as needed with the goal of increasing IRR to 80%. In the final four interviews analyzed, the IRR was above 80% for both researchers.

Sarah and Alexis used IRR calculations to refine code definitions when the IRR was below 80%. The clarification of definitions formed the finalized codebook that ensured both Sarah and Alexis were in agreement on code definitions so that both researchers would be able to identify the same codes in the same places within a given interview transcript. This process overall assures research quality, and we were then able to apply the codes from the final codebook to each interview transcript. After coding all of the interviews with the final codebook, Sarah and Alexis looked for trends across participants and potential ways to group the codes into overarching categories that could answer the research questions. Finally, these trends were used to find key takeaways and themes regarding the participants' experience related to their transition to virtual team projects.

Results
Based on the interview data from the eight interview participants, 10 codes were defined to describe the team dynamics of the participants' teams after the transition online, as seen in Table 1.

Table 1. Final Codebook after Performing Inter-Rater Reliability

Code	Definition	Mentioned By
Communication Difficulties	Student expresses less effective communication with team members through communication platforms as opposed to in person communication (not due to timing nor technology) - having a harder time "being on the same page"	5 out of 8 participants
Decrease in Productivity	Student expresses lack of productivity during online team meetings	2 out of 8 participants
Delayed Communication	Team experienced extended periods of time without a response from other teammate(s)	6 out of 8 participants
Delegation	Impact of assigning roles to individual team members and overall distribution (or lack thereof) of tasks required by the project	8 out of 8 participants
Lack of Motivation	Team member(s) show a lack of motivation after moving online	8 out of 8 participants
Meeting	Team member expresses challenge of getting team to meet after moving online due to scheduling	8 out of 8 participants
Relationship Formation	Student expresses impact of getting to know teammates for online project compared to in person	8 out of 8 participants
Technology	Impact of technology or difficulties with technology when moving online (e.g., Wi-Fi, software)	8 out of 8 participants
Time Difference	Student expresses change in team dynamics (or lack thereof) as a result of time zone differences after moving online	7 out of 8 participants
Timeliness	Student expresses effect of project parts not getting completed in timely fashion for online project (e.g., rushing to get things done for deadline, member not doing part on time)	7 out of 8 participants

How Moving Online Impacted the Team Dynamics
Participants' responses produced key takeaways regarding the impact moving online had on team dynamics: students struggled with procrastination and consistent communication due to a lack of motivation, with having a cohesive understanding of the project objectives, and with full group participation. In investigating how moving online impacted the team dynamics we explored participant responses that included the codes Communication Difficulties, Delayed Communication, Lack of Motivation, and Timeliness.

Participants found it difficult to properly communicate and harder to get their ideas across online than they could have in person. Specifically, participants Pam, Robert, Toby, Angela, and Creed mentioned that they struggled with group members being on "the same page" with regards to the project requirements and group tasks.

Additionally, participants had difficulty getting all team members to respond or show up to virtual meetings. One specific quote from Robert stands out as an example of an overlap of codes Delayed Communication, Lack of Motivation, and Timeliness:

> "I was the informal leader, because I felt like I was the only one with motivation to actually finish the project. And so I was just trying to get them to do stuff. Because you know, we were running up on one of those deadlines. And you know, no one was saying anything. No one was doing anything to work towards it. So I felt like I had to do something."

This quote from Robert shows how a lack of motivation of his team members affected the progression of their project because they were not responding or completing their assigned parts of the project before deadlines approached. Responses from Pam, Toby, Phyllis, and Angela support Robert's struggle by explaining that their teams had difficulties with motivation to meet and to work on their individual tasks.

Over half of the participants said that they struggled to get group members to respond to text and GroupMe messages, and unfortunately, there was not another way to get in contact with teammates aside from those online resources since students could not meet in person. For example, Pam mentioned a struggle with teammates responding to group messages:

> "But then when you're virtual and someone isn't responding to their text, you're like, 'well, what else can I do? Because, like, it's not like I can go over to their room and like, drag them out,' you know? And so that was one of the issues, I guess."

Based on the participants' responses it seemed that if a team member did not want to be contacted, then there was not much that the rest of the team could do besides redelegate that student's work.

Toby and Phyllis found that students not having a clear understanding of the project made it difficult for students to begin the tasks required to complete it. Toby mentioned that after reaching out to one of his team members, he expressed to him "I have no motivation. I don't really understand this project. And I don't think - it's like I don't even know where it gets started". Without a clear understanding of the team's goals, members struggled with staying motivated to complete the project virtually and in a timely manner.

Due to the struggles from communication and motivation issues, participants (Pam, Toby, Robert, Creed) mentioned struggling with procrastination or rushing to complete the project at the last minute. These obstacles caused groups to be less efficient and created more difficult team dynamics during the online team project.

How Team Structure Impacted the Online Team Experience
Participant responses that included the codes of Delegation and Relationship Formation provided insight on how team structure impacted the online team experience. In teams where students are already familiar with one another, members had a better grasp of the individual capabilities and

strengths of its members. Because of this connection, teams tended to feel more confident in electing team roles and could take less time delegating, which allows for an effective team structure based on how the team works together. Participants found it difficult to effectively delegate tasks when they did not know their team members. Group members, particularly informal team leaders (i.e., leaders that were not assigned by the professor), struggled with directness, utilizing strengths of team members, and teammates not completing their parts. When teammates understood each other's expectations and strengths, delegation was more effective.

Pam explained in her interview that without knowing one's team members, it was more difficult to determine how direct to be when assigning tasks:

> "with some people, I'm like, 'Hey, you have to do this' and like I feel comfortable saying that but like, when it's like people you don't know sometimes it like, I feel like it hinders your efficiency because you're like, 'well, I don't want to seem like I'm being too pushy about it.'"

Pam found that her lack of connection with her teammates made her uncomfortable delegating roles, and she stated that this discomfort could have hindered their project.

Many of the participants noted that knowing their teammates would have been or was beneficial in delegating tasks. The planning behind task delegation using knowledge of their teammates had an impact on the success of the project. For example, Robert originally did not evaluate each individual's strengths and instead assigned each person parts without a specific direction. He later found that the roles had to be redistributed because group members did not know how to do their parts, so the tasks were then divided by strengths and were more successfully completed. Similarly, Stanley noted that when delegating tasks for their virtual team project, pairing team members with tasks that fit their major helped in keeping the project going smoothly by having computer science majors complete the website and the mechanical engineering majors focus on product design and feasibility. When team member strengths and weaknesses, work ethic, and communication expectations were already understood, delegation of tasks was much more effective in completing the virtual project. For example, when asked if he felt like knowing his team members helped with going virtual, Robert stated "Definitely. Yeah. Just kind of understanding what to expect with how team members communicate, especially. I think that's a really big deal." Similarly, Jan said that knowing her teammates while transitioning online allowed them to "trust each other's judgment on different things" because "we knew our strengths and weaknesses."

On the other hand, one participant described drawbacks in knowing your team members previously. Toby explained that "I know one person was having a personal issue and we had a conversation and I basically did her role in the project because I knew like, I mean, she lost her support group" after moving online. Because Toby knew his teammate personally, he took on more work out of concern for her well-being. "But as far as being there for each other," during quarantine, Toby stated, "I think it did help" that the team members were already familiar with each other.

In both Pam and Toby's situations, it appears that they each stepped into a leadership role in order to delegate tasks and/or ensure the project got completed. Making up for teammates who were "slacking" or for those who were not able to finish everything delegated to them was

common in the responses of the participants. Angela, Phyllis, Robert, Stanley, and Toby spoke about the challenge of when team members would not complete their share of the online team project. It was found that informal leaders, when faced with someone who was not doing their share of the work, tended to assume the extra work themselves. This shift in responsibility caused group structures to be unbalanced and caused the informal leader to complete an excess amount of work.

In groups that did most work individually, a large focus at the end was to make sure that these delegated parts eventually became cohesive. Because the projects mentioned by participants were a minimum of one month long, the deliverables were greater than those of a week-long project, which meant finalizing each task and combining them into an integrated product made the final deliverables stressful. Many individual parts were being finished close to the deadline, but groups also had to put in the extra work at the end to integrate each person's work into one connected final project. Executing the completion and integration of all parts of the project was stressful in a short amount of time. Overall, delegation affected the team dynamics by creating group leaders who thoughtfully assigned tasks or undertook more work, while relationship formation helped to increase trust in each other and accomplish the delegation.

How the Type of Meeting Environment Used Impacted Team Dynamics
Lastly, Decrease in Productivity, Meeting, Technology, and Time Difference are all codes that apply to investigating how the type of meeting environment used impacted team dynamics. An overarching issue that students faced were unanticipated issues such as WIFI, weather, and general interruptions from moving back home once school became virtual. These issues delayed students in completing their project because virtual meetings were less productive and they had difficulties getting all team members to meet together virtually. Although transitioning online presented teams with time zone differences, struggles with meetings arose mostly from team member punctuality and attendance rather than an issue with differing time zones. When team members were all available to meet, many faced issues with the platforms used for their projects, such as non-collaborative software where only one member could work at a time.

Toby mentioned during his interview that when his whole team met virtually via Zoom, the meetings were less productive than in person because only one person could speak at a time, as opposed to while in person the team could split up to talk about different parts of the project at the same time. This observation from Toby connects Decrease in Productivity to both Meeting and Technology. This explanation and other participants' responses suggest that creating a space that allows students to meet and work, but also be able to work individually would be beneficial.

All participants stated that making time for meetings was an obstacle for their group. Participants explained that some members in their group would cancel or not attend meetings at all. Phyllis explained that in-class project work time was beneficial for scheduling and keeping members obligated to attend meetings. Because students were required to attend class, having project work time during class ensured the attendance of all team members.
Seven of the eight participants mentioned the code of Time Difference in their interviews. Stanley stated that the time zone difference that was created between teammates after going online made it more difficult to know "how to schedule stuff out and just when to communicate with people". Angela stated it was:

> "a struggle either way, whether you're in person or online, just kind of to see everybody's schedule and find times that work in a large group...but I think us being home and then one of the members being in a different time zone just kind of exemplified that struggle a little bit more".

As students were suddenly sent home and their projects became virtual, it became slightly more difficult to schedule team meetings because teammates were possibly in different time zones while they had previously all been in Eastern Standard Time.

However, most participants stated that the time zone difference between teammates after transitioning online and moving home "wasn't too bad" (Jan), "wasn't that big of a deal" (Pam, Phyllis), or "was not a large problem" (Creed). A common finding was that "as long as we specified the time zone when we were talking about meeting times, it wasn't an issue" (Robert).

So while the Productivity, Meeting, and Technology codes were all aspects of virtual team projects that were negatively impacted, the code Time Difference was not largely a negative influence on team dynamics after moving online. However, in most classes the time zone difference was only one hour.

Most students in the semester of Spring 2020 did not have a lot of exposure to Zoom or other virtual meeting software and had trouble with the selected online platforms. Robert, Phyllis, and Stanley found the platform their professors chose difficult to work on because it was non-collaborative software, meaning only one person could work on the project at a time. Creed mentioned that one thing he found beneficial to his experience completing a virtual team project was that his professor took time to walk through and describe online resources for them to use.

Issues with consistent meeting times and quality challenged team dynamics and required students to work extra diligently on their group's behalf in order to make up for inefficiencies and obstacles that a virtual workspace entails.

Discussion
Upon researching what others have studied with regards to virtual team projects, we found that multiple studies reported similar trends in terms of team dynamics, meetings, and efficiency. An industry related study showed evidence stating that routine and consistent meeting times can be instrumental to a virtual team success [12]. Because all participants in the study of the team dynamics during the transition online deemed scheduling meeting times an issue, establishing a regular meeting time each week could be beneficial not only in industry, but in an academic setting as well. Additionally, it was stated in another study that "it is important for instructors of corresponding courses to keep students motivated; this has significant positive correlation with learning effectiveness" [13]. Based on this information and the fact that all eight of the interview participants had difficulties with motivation, it could be beneficial for professors and/or teaching assistants to help students remain interested in order to keep them motivated. While battling these inner difficulties, teams must also overcome technological struggles. As put by Chinowsky, "technology will not guarantee the success of a virtual team, but it can cause the failure of the team" [14]. Obstacles involving software or internet connectivity within the team setting must be addressed and acknowledged to avoid issues in team dynamics and meetings, such as, in our study, students having slow internet connection after moving back home due to the move online.

Since these troubles with technology may not always be foreseeable, it is necessary to have the forethought to plan ahead, so that teams can complete their projects efficiently and in a timely manner. Technology constraints tend to have an effect over various parts of virtual team projects (i.e., meetings, delegation) in the literature above and have been consistent with our study's findings.

Implications for Practice
Tools could be implemented into virtual course projects to help ensure that teams are not only successful in completing their projects, but also that the delegation of tasks, communication between team members, and meetings promote productivity.

Pam suggested an assigned planning document for the teams to write out steps toward completing the project and which teammates would work to complete each step. Although she described this document as tedious at first, she followed by saying, "looking back, it was actually really helpful because I don't think we would have gotten anything done if we did not have that document". This document would allow for teams to set expectations in a written format so that all members are in agreement for team goals and deadlines. This planning document would help the team keep its intended timeline to finish goals and overall help the team dynamics be more communicative and effective. Another participant, Stanley, suggested similarly that one thing that helped his team was planning out a timeline with goals for each week so they could stay on track to finish the project on time. Finally, multiple participants mentioned in their interviews that it would have been or was helpful to have a set, required team meeting time each week. Both Jan and Phyllis liked having a scheduled meeting time for their teams because it ensured that all of their team members would be at the meetings. Scheduling recurring meetings for the team would help to keep all participants involved in the project and maintain a positive team environment.

Based on the suggestions from the participants and their responses to interview questions, implementing tools such as weekly planning charts or weekly scheduled team meetings are ways in which students could better manage the productivity of their meetings and ensure tasks necessary to their project are getting completed in a timely manner. These implementations would help the group have a better general understanding of the team's tasks, more effective delegation techniques, and more consistent and productive meetings. Not only would these tools help the students in their current projects, but they would also prepare them for their senior projects and projects in their future careers, as weekly updates and meetings are common in those situations.

Conclusion and Future Research
In our study, we identified how moving online, team structure, and meeting environment impact the team dynamics of undergraduate engineering groups. Moving team projects online led to issues regarding motivation of team members and general understanding of the team's goals. The structure of the teams lent to more effective delegation when the team members knew more about one another, such as their strengths and weaknesses, which was more difficult for teams after moving online. The virtual meeting environment led to issues with WIFI connection, technological issues, and the use of non-collaborative software.

As this study was conducted at a single institution, future work should explore the team dynamics of virtual undergraduate engineering teams at other universities across the country. In addition, most students in our sample were in their first year at the University, so future studies should expand on this work by studying teams of students who are in the later years of their undergraduate engineering course work. One unique opportunity is to explore the experiences of virtual senior design teams. These projects are often designed to be a transition from academic projects to industry projects, which is a prime area for research given that virtual teams are becoming more common in industry. Compared to the projects in this study, the projects for senior design teams are likely to be longer term with greater stakes and technical challenges. Studying the team dynamics of virtual senior design teams would allow researchers to determine if a higher complexity project amplifies the struggles found in this study and inform approaches that can be used to better prepare students for industry.

Future research can expand on this work by exploring the team dynamics of interdisciplinary virtual teams. It is likely that the experiences and challenges faced by interdisciplinary teams will be different than those of engineering student only teams given that a wider range of experiences, backgrounds, and ways of knowing will be represented in an interdisciplinary team. Likewise, future work can investigate how larger environmental obstacles, such as a greater time difference impacts team dynamics. In this study, most teams only had to navigate a one-hour time difference. Outcomes from a study on larger time differences would have implications related to global teams in industry, which must account for greater time and cultural differences.

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