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Understanding Remote Student Motivation in Hybrid and Remote Engineering Lab Modes

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Abstract

The evidence-based practice paper describes a study investigating remote students' intrinsic motivation in different engineering lab modes. One of the challenging tasks in engineering education is to improve and maintain students' motivation and retention. During the COVID-19 pandemic, students at some universities chose to be either online or in-person, which generates a problem for educators on how to keep hybrid teamwork and collaboration high quality. It is widely self-reported that remote students feel isolated from the in-person team members due to a lack of social presence. The in-person students also complain about less engagement from remote students. Self-determination theory (SDT) specifically addresses the relationship between human motivation and relatedness (meaningful relationships and interactions with other people). There are two key research questions to be answered in this study: one question is how self-determination theory may be used to understand remote students' motivation; the other question is which lab collaboration mode is best for remote students' intrinsic motivation: in-person centered; remote-only, and in-person only; or hybrid mode. An IRB protocol was approved to conduct a post-lab survey, centering on students' feedback of those three modes in Fall 2020. Both qualitative and quantitative answers were assessed. The results showed students are more engaged in the lab process in both hybrid and in-personal-centered labs. Therefore, this study suggests that having a mixed-student learning environment improves remote students' participation and motivation.

Introduction

During the COVID-19 pandemic, many students remotely participate in engineering lab activities, which poses many learning challenges. As many engineering labs are team-based, the remote students generally feel distant from the team members due to a lack of physical, social presence or communication issues caused by the hybrid class mode. Moreover, team performance will be significantly impacted if remote students have difficulties engaging in physical experiments and participating in team discussions.

Self-determination theory (SDT) is widely regarded as a well-established theoretical framework in educational psychology [1]. It states that intrinsic motivation is strongly correlated with the satisfaction of three major psychological components: autonomy, competency, and relatedness. Autonomy refers to a sense that individuals control their own decisions and exercise their freedom of choice to continue in whatever way they see as best. Competence refers to an individual acquiring suitable knowledge and skills for personal success. Relatedness refers to a feeling of community and shared common objectives. Once all three of these components are met in a particular social context, the motivation will be internalized and become intrinsic [2]. This study aims to use Self-determination Theory (SDT) to explore the hybrid class mode and improve remote students' intrinsic motivation. This paper focuses on answering two research questions:

1. How can SDT be used to improve remote students' relatedness by varying the interaction level between in-person and remote students?

2. Which lab mode is best for improving remote students' intrinsic motivation: (i) **Remote-only and In-person-only Lab 1:** remote students complete the customized virtual lab while in-person students complete the in-person lab separately; (ii) **Hybrid Lab 2**: remote and in-person student work equally on collaborative lab tasks; (iii) **In-person-centered Lab 3**: in-person student takes the lead on lab tasks while communicating with remote students?

Literature Review

To deal with the need for more flexible learning, educational research and development during the COVID-19 pandemic aimed at providing a richer, more engaging remote learning through the creation of the synchronous hybrid virtual classroom. The concept of the hybrid virtual classroom comprises one group of learners who participates in the course on campus, and simultaneously other individual learners participate in the course remotely from a location of their own choice by connecting to the same platform [3, 4].

Having a class of hybrid mode has many organizational as well as pedagogical benefits. Firstly, the hybrid mode provides a wide range of alternative participation modes and enables students to choose between participation modes daily or weekly. Secondly, the hybrid mode provides learning activities in all participation modes, which lead to equivalent learning outcomes. Thirdly, the hybrid mode allows students to have equitable access to all participation modes.

The lack of presence and relatedness for remote students is one of the major challenges in hybrid mode. Presence is a personal perception of the realness of a virtual environment. Many research groups have been trying to define the factors that contribute to presence. Sheridan defined presence as an individual's ability to feel physical presence remotely [5]. Present awareness can be created through the engagement of human senses, an arrangement of the surrounding environment, and the application of remote technology.

Sense of relatedness or connectedness, on the other hand, was regarded as a different psychological concept but related to the presence[6]. That may function as a motivational powerhouse that drives engagement and achievement [7-9]. Relatedness is described as "the need to feel belongingness and connectedness with others" (Reis, et al. [10], White [11], Eisenberg, et al. [12], DeCharms [13], Deci and Ryan [14], Baumeister and Leary [15]). Researchers have noted that learning environments promoting a sense of relatedness to teachers, parents, and peers can strengthen motivation and have a positive effect on school outcomes (Chen and Jang [16]; Ryan and Deci [17]; Ryan and Grolnick [18]; Ryan, et al. [19]). Feelings of relatedness, measured in terms of "school climate" and instructor-student relationships, have been linked to outcomes including self-efficacy, engagement, interest in school, higher grades, and retention (Furrer and Skinner [20]; Inkelas and Weisman [21]; Inkelas, et al. [22]).

Relatedness has often been discussed along with autonomy and competence as one of the psychological needs for intrinsic motivation [23, 24]. Skinner, et al. [25] argued that "relatedness tends to be overlooked as a self-perception in the academic domain." In the past, relatedness is normally considered in the context of team-based learning such as collaborative and group learning [26-28]. While these types of team-based learning experiences are believed to have positive impacts on improving students' motivation, team-based lab objectives do not seem necessary to interactive activities and may be completed via allocated individual tasks, eliminating chances for building relatedness. For example, many engineering projects encourage students to work on individual tasks and document the progress as a team-based final report. Because of that, there are very limited interactions between the students. In order to truly foster a sense of relatedness within a team, the lab design would ideally support "feeling connected to others, to caring for and being cared for by those others, to having a sense of 'belongingness' both with other individuals and with one's communities" [29].

Feelings of relatedness with peer students — interpreted as perceptions that a student consider himself or herself as a valued member of the group and care about the other's needs — are suggested in the past literature to bolster students' academic learning in the school environment [30-32]. It is appropriate for students to rely more on their peer learning community as opposed to their family of origin as they progress through schools and colleges [33].

Being spotted as early as secondary education, relatedness could facilitate students' comfort in taking learning risks and asking others for help on the learning materials [34]. In contrast, lacking perceptions of belonging with their peer students may generate anxious thoughts [35]. Relatedness increases students' sense of belonging, promote class engagement and potentially improve academic achievement [36, 37]. Miller, et al. [38] suggests that the opportunities that hybrid courses and other hybrid classes present provide significant opportunities for improving educational outcomes. In another study being carried out at the University of Wisconsin, Aycock, et al. [39] have developed hybrid learning based on their teaching styles, course content, course size, and course goals. This resulted in a more comprehensive in-class discussion, higher student self-achievement, better performance on exams, and better quality of projects.

Experimental Methods

An introductory engineering program has 300 students enrolled per semester. Ninety percent of students enrolled in the class are first-year students. The motive of the study was to collect information about the three different lab modes and to determine which modes can best improve students' learning outcomes.

Figure 1 shows the remote-only and in-person-only Lab 1. The in-person students work independently, and no communication is required between in-person and remote students.

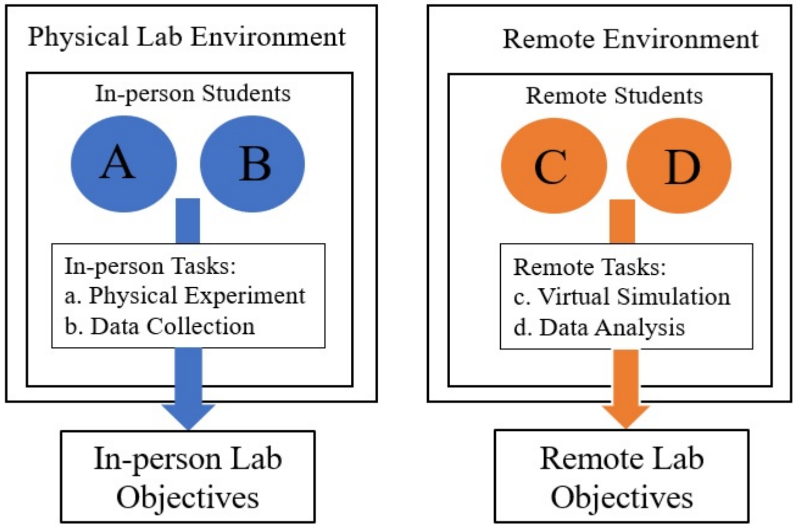


Figure 1. The lab structure for remote-only and in-person-only Lab 1. Each blue circle represents an in-person student, while each orange circle represents a remote student. The blue and orange arrows show the students work towards their own lab objectives.

Figure 2 shows the hybrid Lab 2. All the lab tasks are collaborative, which require in-person students to communicate with remote students over Zoom.

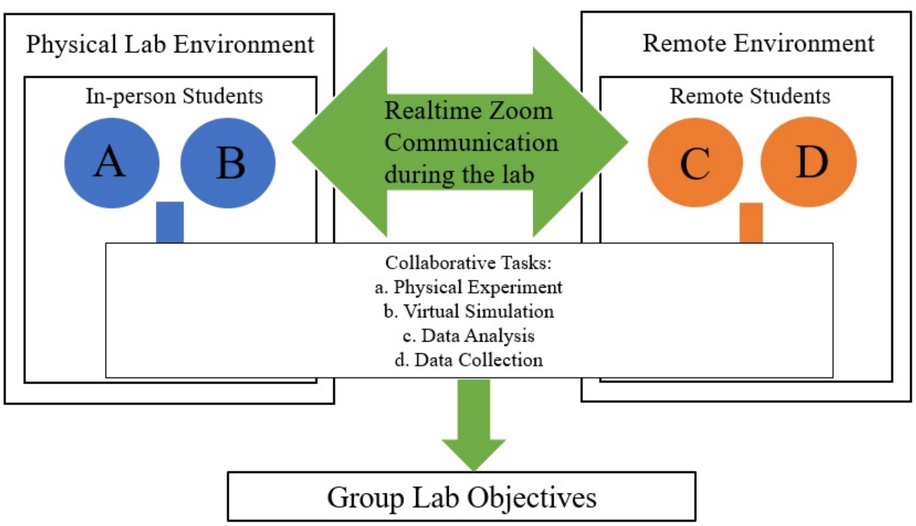


Figure 2. The lab structure for hybrid Lab 2. Each blue circle represents an in-person student, while each orange circle represents a remote student. The green arrow shows the students work towards their group lab objectives.

Figure 3 shows the in-person-centered Lab 3. Both in-person and remote students have their own tasks to complete. Meanwhile, the in-person students are leading the collaborative tasks.

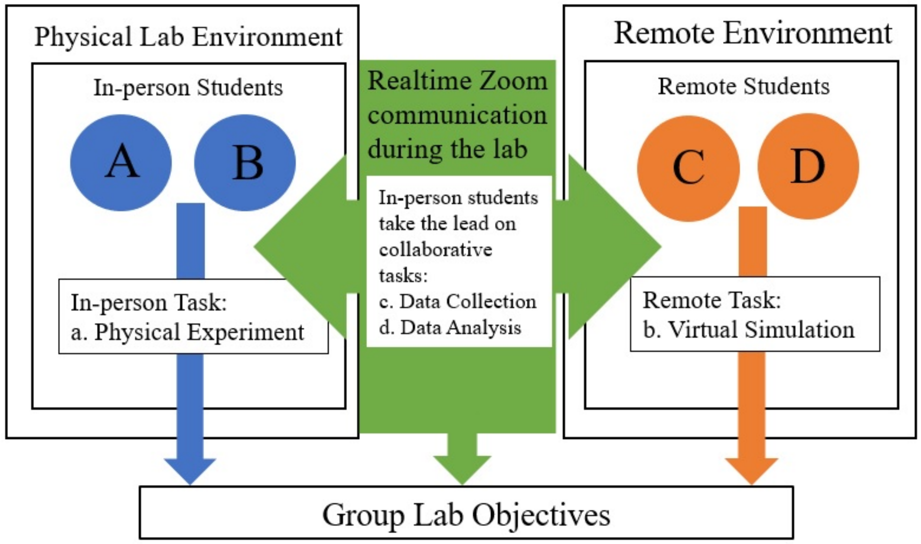


Figure 3. The lab structure of in-person-centered Lab 3. Each blue circle represents an in-person student, while each orange circle represents a remote student. The arrows show the students work towards their group lab objectives.

The survey was approved by IRB protocol (No. IRB-FY2021-4847) and given to the students at the end of the fall semester, 2021. The students were not allowed to take this survey if they are under the age of 18. Out of the 300 students polled, 92 responses were recorded and analyzed. The survey was developed using questions derived from the Intrinsic Motivation Inventory (IMI) [40]. There were 12 quantitative and four qualitative questions developed on the Qualtrics XM® platform (**Table 1**). Students were asked questions about their demographics, their lab learning experience, benefits as well as challenges of hybrid lab.

Table 1: Likert scale quantitative questions and open-ended qualitative questions

Quantitative questions	Likert Prompt
1. I felt really distant to team members 2. I really doubt that team members and I would ever become friends 3. I really feel like I could trust team members 4. I would like a chance to interact more with team members 5. I would really prefer not to interact with team members in the future 6. I don't feel like I could really trust team members 7. I think it's likely that team members and I could become friends 8. I feel really close to team members 9. I am satisfied with my performance at this task 10. I was pretty skilled at this activity 11. This was a lab that I couldn't do very well 12. I enjoyed doing this lab very much	Indicate the degree to which each of the statement below: Strongly agree (7) Agree (6) Somewhat agree (5) Neutral (4) Somewhat disagree (3) Disagree (2) Strongly disagree (1)
Qualitative questions for hybrid lab 2	
1. What are the main benefits of working in a hybrid lab? 2. What are the main challenges of working in a hybrid lab? 3. What are the important skills needed in industry as organizations move to remote work? 4. What skillsets have you learned from the labs that could be transferable to the future in your careers?	

The Intrinsic Motivation Inventory (IMI) is a multidimensional measurement device intended to evaluate participates' subjective experience regarding target activity in laboratory experiments [40]. It has been used in several past experiments related to intrinsic motivation and self-regulation [41-43]. The instrument assesses participants' relatedness (Q1 — Q8), perceived competence (Q9 — Q11), and interest or enjoyment (Q12) while performing a given activity, thus yielding three subscale scores. The relatedness subscale covers interpersonal interactions as well as friendship formation. **Figure 4** shows the procedure for calculating a relatedness score for each lab mode.

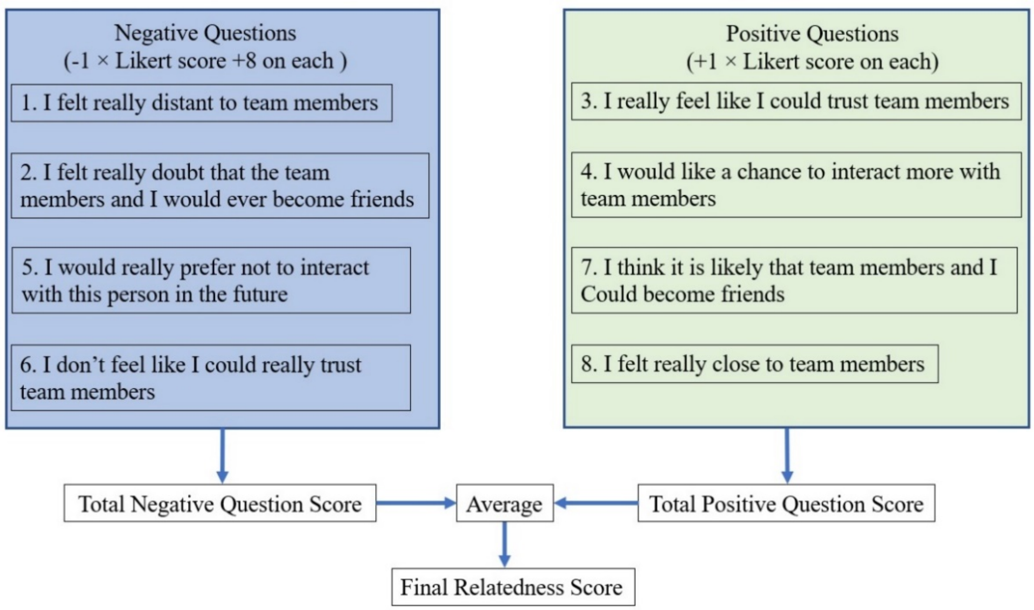


Figure 4. **Calculation method for relativeness score for Lab 1 — 3.**

As for the qualitative analysis, coding method was used to extract keywords from students' responses. According to the qualitative questions, four categories were created: benefits of participating in Lab 2, challenges of participating in Lab 2, remote working skill, and transferable skill. In each category, the authors read reflections sequentially by student and identify common keywords. The number of common keywords was counted, and the pie charts were created to display the popularity of common keywords in each category. Moreover, some student answers to the qualitative questions were used to provide more insights.

Results and Discussion

Quantitative Assessment for Remote-only and In-person-only Lab 1

Figure 5 shows 6 % of students strongly agreed that "I felt really distant to team members." in Lab 1, which is much higher than 2 % of students in Lab 2 (**Figure 6**) or Lab 3 (**Figure 7**). Overall, there are 25 % of students feel they are distant to team members. This indicates less student interaction in Lab 1. Moreover, 12 % of students somewhat agreed, agreed, or strongly agreed that "I would prefer not to interact with team members in the future." The student feedback is expected as Lab 1 was designed to separate the physical lab component from its virtual counterpart so that in-person and remote students would have completely different lab tasks. It is not a requirement for them to exchange information during the lab activity.

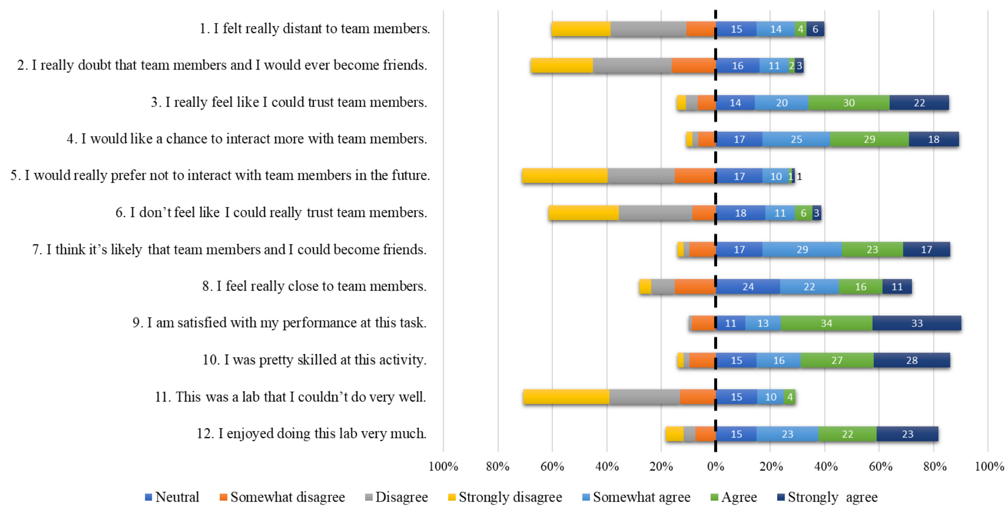


Figure 5. Quantitative question responses for remote-only and in-person-only Lab 1. All the bars are stacked to align with the dotted line (n=92).

Quantitative Assessment for Hybrid Lab 2

Figure 6 shows only 8 % of students who somewhat agreed, agreed, or strongly agreed that "I do not feel like I could really trust team members". Also, 35% of students strongly agreed that "I would like a chance to interact more with team members". According to **Figure 2**, Lab 2 was designed to encourage collaborative work between remote and in-person students. It means the students would need to communicate continuously with each other and share the information to complete the group lab objective. During this process, they have to rely on mutual trust and constantly monitor each other's work progress. That explains why the students feel more confident in team-based work.

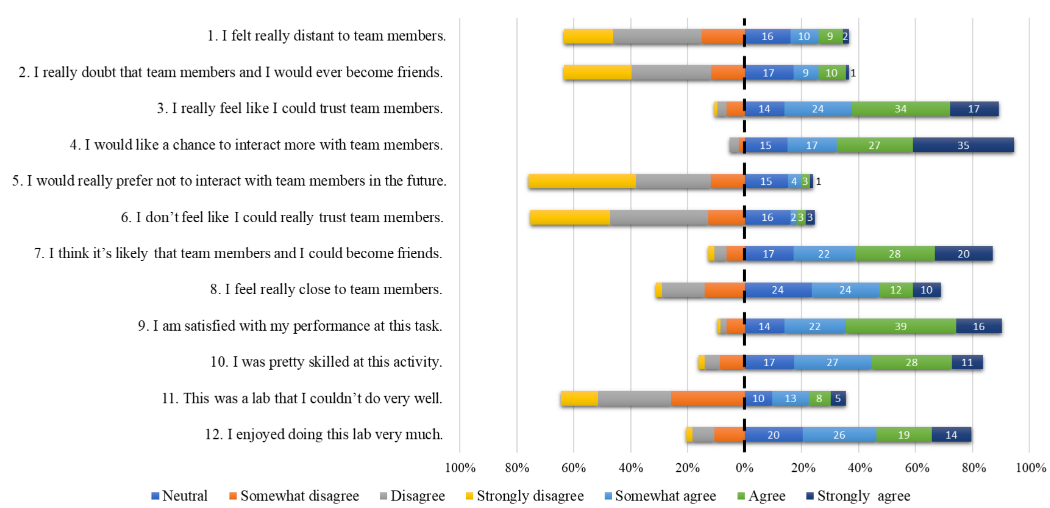


Figure 6. Quantitative question responses for hybrid Lab 2. All the bars are stacked to align with the dotted line (n=92).

Quantitative Assessment for In-person-centered Lab 3

Figure 7 shows more than half of students somewhat agreed, agreed, or strongly agreed that "I think it's likely that team members and I could become friends" and "I am satisfied with my performance at this task". Although there were fewer tasks for remote students, their data analysis result was still critical for completing the group objective. Through the lab activity, the in-person students acted as team coordinators and collected information from remote students. This constant engagement generated a positive teamwork attitude and better learning outcomes for remote students.

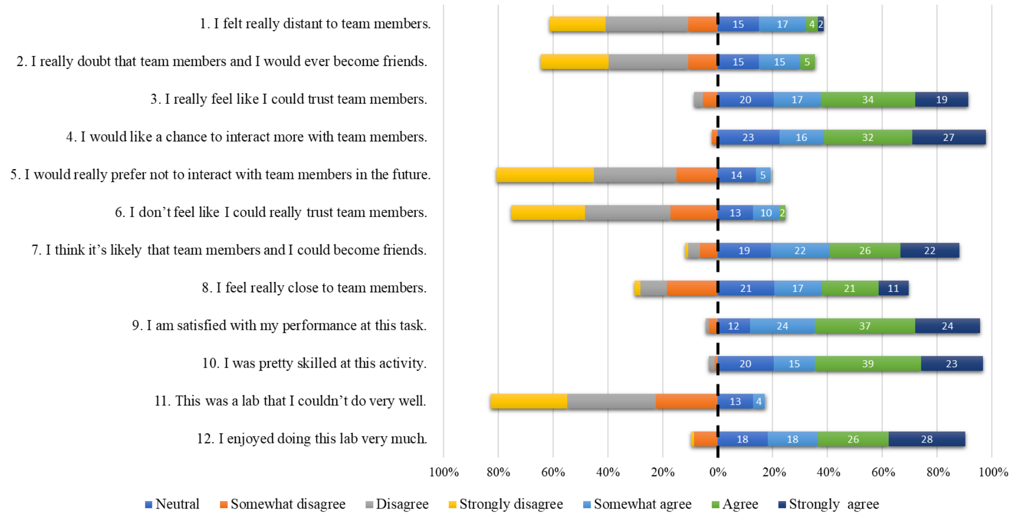


Figure 7. Quantitative question responses for in-person-centered Lab 3. All the bars are stacked to align with the dotted line (n=92).

Table 2 shows the statistical comparison between different lab modes (1 = strongly disagree, 7 = strongly agree). The mean values are rounded to two decimal places.

Table 2. Statistical comparison between lab modes (n=92).

Qualitative Questions	Lab 1 Mean	Lab 2 Mean	Lab 3 Mean
I felt really distant to team members	3.11	3.04	3.00
I really doubt that team members and I would ever become friends.	2.83	2.92	2.83
I really feel like I could trust team members.	5.20	5.28	5.32
I would like a chance to interact more with team members.	5.20	5.69	5.59
I would really prefer not to interact with team members in the future.	2.57	2.36	2.24
I don't feel like I could really trust team members.	2.94	2.53	2.54
I think it's likely that team members and I could become friends.	5.05	5.17	5.19
I feel really close to team members.	4.41	4.26	4.47
I am satisfied with my performance at this task.	5.67	5.33	5.62
I was pretty skilled at this activity.	5.33	4.90	5.55
This was a lab that I couldn't do very well.	2.59	3.28	2.33
I enjoyed doing this lab very much.	4.98	4.74	3.83

Using the data from **Table 2**, the relatedness for each lab mode can be calculated. For each lab, there are four major tasks: physical experiment, virtual simulation, data analysis, and data collections. According to **Figure 1 — 3**, the number of collaborative tasks for lab 1, 2, and 3 is 0, 4, and 2, respectively while the number of total lab tasks remains as 4. The percentage of collaborative tasks was calculated using **Eq (1)**. To normalize the results from 2-member or 4-member student teams, the student team was suggested to assign one in-person representative and one remote representative for communication.

$$Percentage\ of\ Collaborative\ Tasks = \frac{Collaborative\ Lab\ Tasks}{Total\ Lab\ Tasks} \times 100\% \qquad (\mathbf{1})$$

Figure 8 shows Lab 2 and Lab 3 scored higher in relatedness (5.25 and 5.19, respectively) compared to Lab 1 (5.05). The inherent flexibility of hybrid courses makes it easier for students to balance their personal lives with their academics. It also gives students options to customize their educational experience. With students arriving to class with different levels of prior knowledge and experience with course content, this format allows them to choose what kind of learning experience works best for them. Similarly, some students learn better online, while some prefer face-to-face class meetings. This helps them engage further in course material and take the initiative in learning.

However, it is noticeable that the relatedness score increases from Lab 2 to Lab 3 while the ratio of collaboration drops from 100 % to 50 %. One possible explanation is that the students were novices in communication and teamwork management in Lab 2. Then they became more prepared in Lab 3.

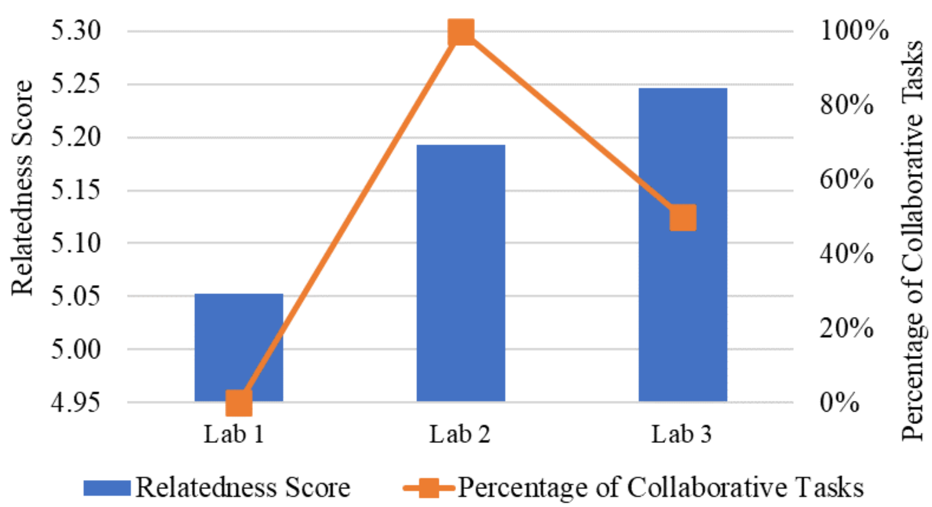
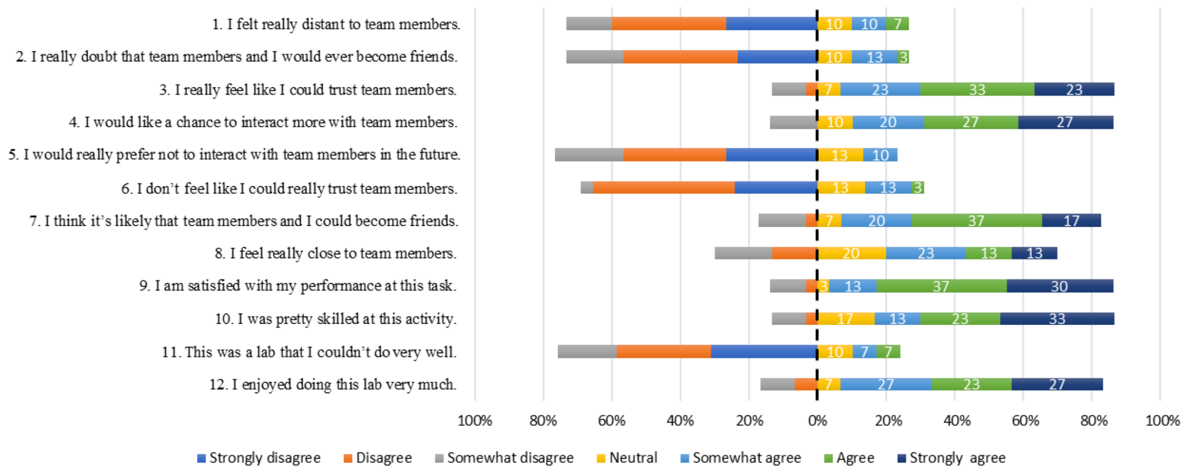


Figure 8. The relatedness score for Lab 1, Lab 2, and Lab 3 at different percentages of collaborative tasks

Quantitative Comparison Between Lab 1 and Lab 3

As both Lab 1 and Lab 3 have in-person and remote elements, it is worthwhile to compare the learning experience of in-person and remote students. **Figure 9** shows there were 7 % of students who agreed that "I feel really distant to team members." in Lab 1. Also, there were 10 % of students preferred not to interact with the team members in the future. All this can be attributed to a lower level of engagement in Lab 1. As the tasks are well-defined as "in-person" and "remote" in Lab 1, it is not necessary for in-person students to communicate with remote students for getting advice or feedback. Although Q9 — Q12 indicate over 50 % of the in-person student were still satisfied their Lab 1 performance and enjoyed the lab activity, this is mainly due to the guidance or help provided by the teaching assistants. Although the lab objectives were met, the students lose the opportunity of being involved in collaborative exercises and may start to develop negative feeling about collaborative teamwork.

(a) Feedback of in-person students working in Lab 1



(b) Feedback of in-person students working in Lab 3

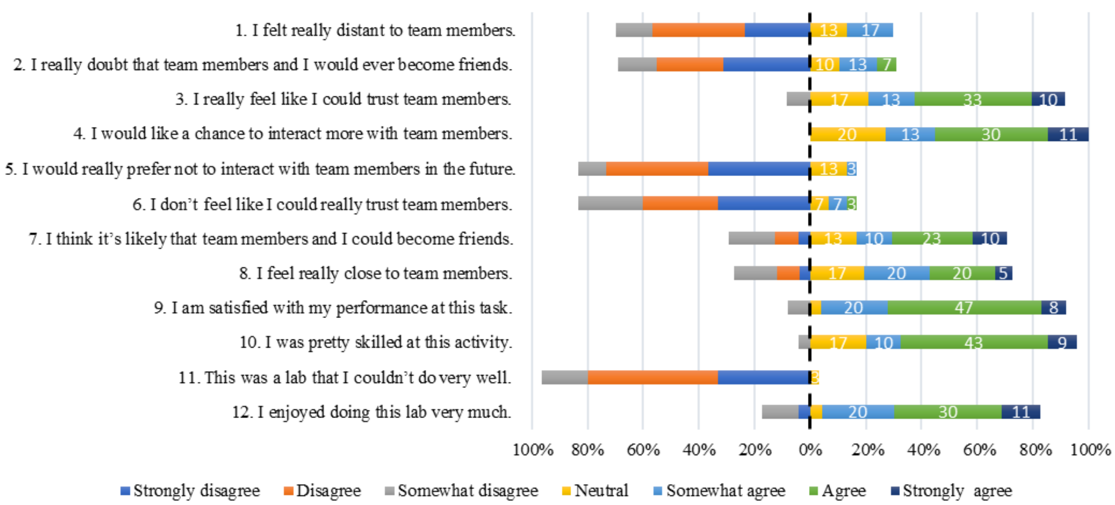


Figure 9. Direct comparison between in-person feedback of Lab 1 and Lab 3.

As for the remote students, none of them strongly felt distant from team members or cannot trust the team members (**Figure 10)** in Lab 3. Also, more remote students were willing to interact with the team members in Lab 3. It means there was a more positive work relationship between the remote and in-person students in Lab 3. As the communication between the in-person and remote student greatly increases the present awareness of the remote students, they felt belonging to the team and wanted to be more involved in the lab activities.

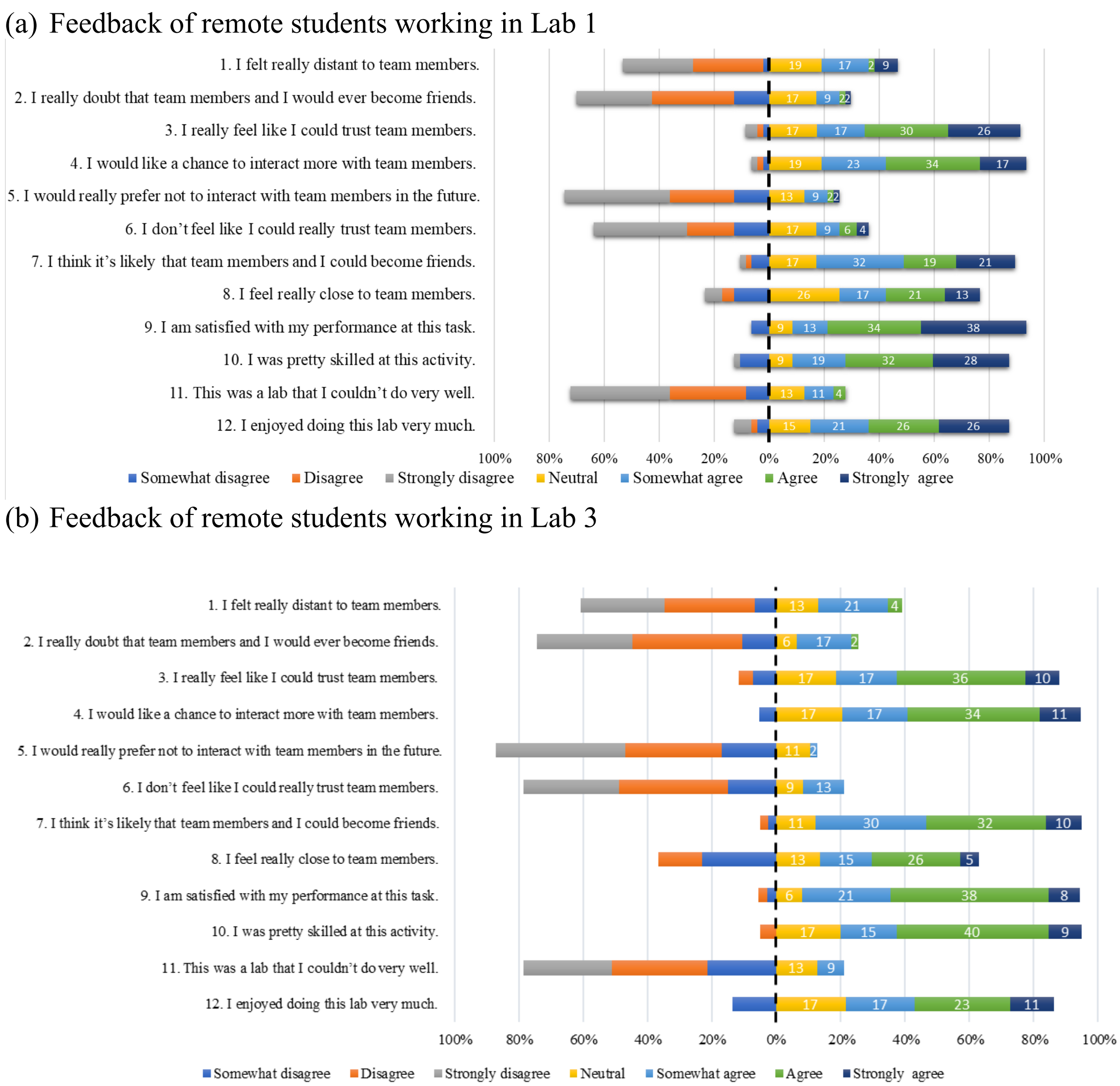


Figure 10. Direct comparison between the remote feedback of Lab 1 and Lab 3.

Qualitative Assessment on Hybrid Lab 2

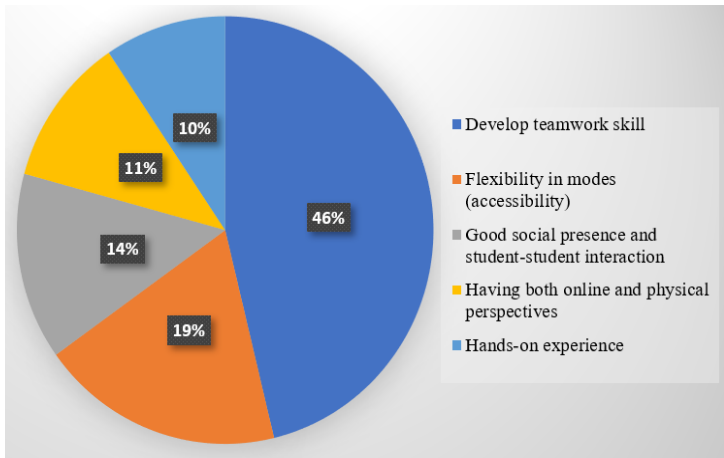
Figure 11 shows the benefits as well as challenges of hybrid lab mode. In general, the top three benefits of having a hybrid lab are developing teamwork skills, flexibility in modes, and good social presence, and student-student interaction. In contrast, the top three challenges of having a hybrid lab are technical communication issues with remote students over videoconferencing software, unbalanced lab design, and problems associated with visualizing the lab. Some examples of the student comments pulled from the qualitative questions are listed below:

- *"The main benefit of working in a hybrid lab was that we were able to interact with the remote students."*
- *"Works are better distributed, and people don't need to repeat the same procedure."*
- *"Some challenges are communication as over zoom is sometimes hard to work together."*

- *"Sometimes the online versions of labs just are not the same, and online students just sit there waiting for stuff to happen."*

These comments show that students perceived one of the major benefits of hybrid lab team-based collaboration. However, the challenges were technological barriers over remote communication and an initial learning curve for team building.

(a) Benefits of Participating in Lab 2



(b) Challenges of Participating in Lab 2

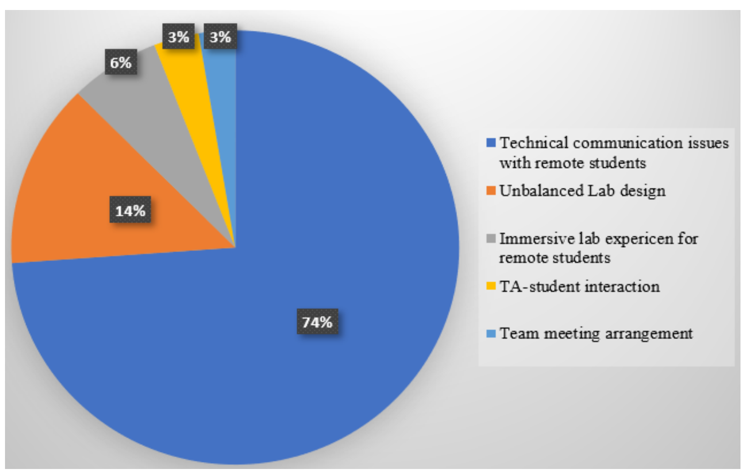
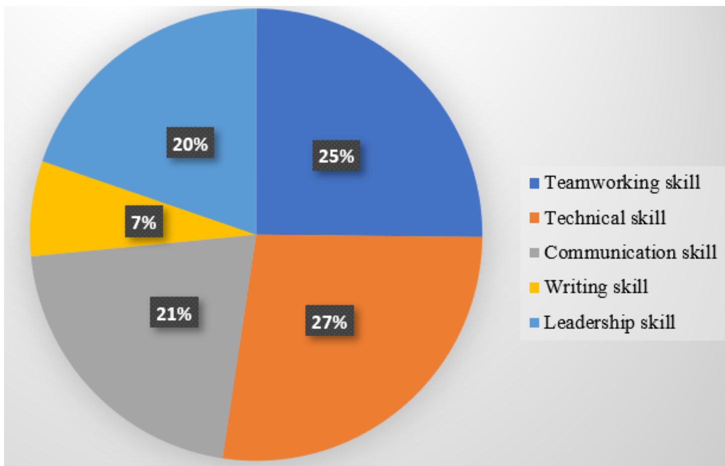


Figure 11. Qualitative question responses regarding (a) Benefits and (b) Challenges of Lab 2.

Figure 12 shows skillset development and students' career preparation. The top three transferable skillsets being developed are teamwork, technical, and communication skills. The top three remote working skillsets are strong communication, task or schedule management, and teamwork skills. The remote students learn how to effectively communicate over Zoom, set team goals, and monitor the team progress. The comments below were pulled from the qualitative questions from the survey. In general students developed better skillsets such as online communication proficiency.

- *"Better communication skills, being able to enjoy oneself even through remote work, some kind of pride in working as a team."*
- *"Skills for working comfortably with PC and laptops. These skills include Zoom proficiency and Microsoft Office knowledge."*
- *"Definitely communication and teamwork, along with other organization and leadership skills."*
- *"I have learned to be able to manage multiple forms of communication at the same time while working on an intensive assignment."*

(a) Transferable Skill



(b) Remote-working Skill

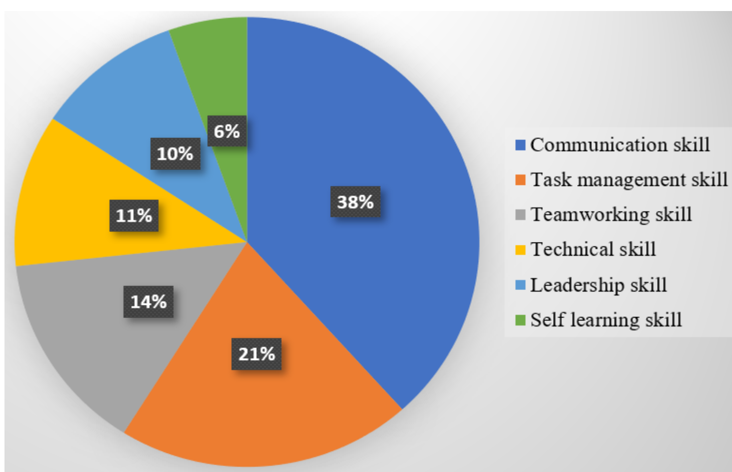


Figure 12. Qualitative question responses regarding (a) Transferable Skill and (b) Remote-working Skill.

According to the Accreditation Board for Engineering and Technology (ABET), one of the general criteria for undergraduate level programs is to "function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives."[44]. The hybrid mode improves remote students' learning outcomes via creating a collaborative and self-learning environment. All these transferable and remote working skillsets help students better prepare for their future academic and career roles (**Table 3**).

Table 3. The potential benefits for acquiring transferable and remote skillsets

Skills	Capstone project at senior year	Future careers
Collaborative Problem-solving	Students need problem-solving skills for their Capstone projects [45].	Collaborative problem solving (CPS) is critical to generate efficiency, effectiveness, and innovation in the world economy [46].
Teamworking	Students need to work as a team during Capstone/final year design [47].	Soft skills like teamwork are increasingly important in business operations [48].
Communication	Students need good presentation skills for class assignments [49].	Effective communication is the key to deliver or share business ideas [50].
Leadership	The learning process of becoming an effective leader and a valued team member must begin through the introduction of leadership skills during undergraduate engineering education [51].	Leadership is essential in organizations to successfully promote a culture of innovation [52].

Conclusion

To answer the first research question, the SDT inventory indicates that increasing interaction between in-person and remote students can improve students' intrinsic motivation in team-based lab activities - the student generally feels more involved and builds a strong bond with other students. Both the quantitative and qualitative results confirm that there is strong interaction ongoing between in-person and online students.

To answer the second research question, both in-person-centered lab and hybrid lab could potentially generate higher relatedness, thus stronger intrinsic motivation than the remote-only and in-person-only lab.

Summary of learning outcomes:

- Lab 2 and Lab 3 could increase the level of interaction between online and in-person students in comparison with Lab 1, as indicated by the relatedness score (5.25 and 5.19, respectively) in comparison with Lab 1 (5.05).
- More positive student interaction was confirmed in Lab 2 and Lab 3. For example, 35% of students strongly agreed that "I would like a chance to interact more with team members." in Lab 2.
- The remote students felt less distant and want to be more involved in Lab 3 compared to Lab 1.
- Lab 2 allows students to acquire teamwork and other transferable skills in the hybrid lab environment, according to the results from **Figures 11 — 12**.

According to SDT, more relatedness leads to the higher the remote students' motivation. In-person-centered Lab 3 had the highest relatedness score, followed by hybrid Lab 2 and the remote-only and in-person-only Lab 1. This suggests the remote students are more motivated to work with team members in Lab 2 and 3, which was also confirmed by the responses from individual survey questions.

This study helps to determine the optimal engagement level between in-person and remote students and choose a lab mode with the strongest intrinsic motivation. The mixing groups of in-person and remote students (Lab 2 and Lab 3) are deemed as the most effective for delivering better student learning outcomes. The results from this paper could be beneficial for both pandemic and post-pandemic curriculum development. The future work is to implement the mixed-student (remote and in-person) lab mode and help the students to develop stronger team-based skillsets.

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