Cohort-Based Supplemental Instruction Sessions as a Holistic Retention Approach in a First-Year Engineering Course

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Abstract

An academic year that began with many students being separated from the university environment due to almost complete online instruction, and additional stress from national crises and revelations of consistent systemic inequities prompted our Supplemental Instruction (SI) program's focus on students' sense of community, motivation, stress management and overall academic and personal success. While the traditional SI model values voluntary attendance, research has shown that regular attendance (i.e. students attending six sessions or more) has the highest impact to students' grade outcomes, retention and graduation rates, as well as their sense of connection, belonging and positive experience in their first year. This complete research paper examines the quantitative and qualitative impact of intentionally creating small, registration-based cohorts of students to regularly attend SI sessions, implemented at our university in a first year engineering course in fall 2020. Our results indicate that (as in other semesters), students who attended SI sessions had statistically significant higher course GPAs than those who did not attend, but an added benefit was that almost 40% of students in the course regularly attended SI this fall, compared to previous fall semesters where only 12-22% of students attended regularly. The rate of D's, F's, Q drops and withdraws (DFWQ rates) for SI students was 2.8% in fall 2020, compared to a 9.1% DFWQ rate for SI students in fall 2019. SI students who had less programming experience (potentially through systemic educational inequities) than their advantaged counterparts, also had statistically significant higher course GPAs when compared to non-SI students who had the same prior experience. The team determined several emerging themes from the survey and interview responses, such as a burgeoning sense of community, comfort with peers over time, accountability and structure, and an awareness of SI session activities as diverse and different than other learning experiences. We hypothesize these all had strong positive impacts on students' overall retention and success in the course.

Introduction

The SI program is an academic support program created in 1973 at the University of Missouri in Kansas City, to improve grades in traditionally "difficult" classes, promote student retention and increase graduation rates. The historically successful and evidence-based SI program was introduced at the University of Texas at Austin in 2015 through a collaboration between the School of Engineering and the campus Learning Center. The supported courses include freshman level introductory courses to Electrical Engineering and Computing (ECE). These are required courses for the ECE students at the university, and report high percentages of D's, F's, Q's (drops), and W's (withdraws).

To improve academic success, traditional SI programs provide voluntary, non-remedial weekly group sessions led by previously successful students known as SI Leaders, who are trained to design and facilitate collaborative activities that combine application of difficult content and transferable study effectiveness skills, with opportunities for practice that requires active engagement of student attendees. The SI model was built upon theories including the mediation of learning by social constructivism and interdependence [1, 2] so while development

of content knowledge and study skills are intentional in sessions, there are often incidental benefits, such as developing interpersonal skills, teamwork and a sense of community and belonging. Previous studies on the impact of SI in engineering courses show that students attending SI sessions have improved performance on exams, final course grades, improved retention rates in engineering programs, and transferable benefits to non-SI course performance [3-12]. The SI program has also been shown to provide learning opportunities that reach greater proportions of minoritized groups (women and ethnic minorities) [6-10].

An important aspect of SI has always been the voluntary nature of the sessions. SI is assigned to historically difficult courses, theoretically reducing the perceived stigma some students may experience using academic support. By avoiding an association with specific student populations and instead enticing all students to attend, SI can create a comfortable, brave and strengths-based learning environment. However, we have found that attendance in these optional SI sessions has remained lower than desired in our engineering courses for the past five years.

A review of literature on student retention in higher education established that holistic approaches addressing students' formal and informal experiences inside and outside of the classroom, taken up by multiple members of the campus community from across departments have the most impact on retention rates [13]. It firmly put the responsibility of student retention on the institution and recommended achievement of higher retention could be accomplished by offering easily accessible academic, personal and social support services. They found that interactions students have with faculty, staff, and peers can directly influence undergraduate retention, and the mechanism of action of this direct influence is that it affects students' sense of community and connection to the university, their ability to navigate the college experience and meet academic expectations. We acknowledge that the SI program could achieve this type of influence, but that intentional planning and action had to be taken to create and enact these holistic approaches.

I. Motivation for Study

The coronavirus pandemic that hit the globe in 2020 forced our university to conduct all our first year engineering courses virtually. Despite previous research on the positive impact of SI on student outcomes in engineering courses (referred to in the Introduction), data from past semesters indicated that the low attendance we experienced in-person would likely be exacerbated by a completely online offering. The research collaborators in this study were most concerned about the impact of reduced community building experiences and relatedness on student motivation. While we did not intend to stray too far from the traditional SI model, this fall semester presented a unique challenge and therefore our attendance strategies in SI would need attention.

The test course that we chose for this research study is a first year required course, called Introduction to Computing (E E 306), that all incoming engineering students in our department are required to take in their very first semester. A bottom-up approach to computing is followed, with topics such as number systems, data types, arithmetic and logic operations, digital logic circuits, and a basic computer model introduced before presenting machine and assembly language programming and debugging, and data structures such as arrays, strings, linked lists and stacks. Due to the wide range of topics covered in some depth in this first year course, it is

historically considered as difficult. A student's performance in this course can therefore dictate their decision to stay within the major.

The diversity in our freshmen engineering population stems not only from demographics, but also from the level of preparation for our rigorous engineering program. A large fraction of our incoming class has some prior computer programming experience but there is also a significant portion of our student body that has little to no programming experience. One study demonstrated that students with prior programming experience taking a series of introductory programming courses achieved a full letter grade higher in the first course than those with no prior programming experience [14]. This is compounded by GPA outcomes within first-year classes, which is a significant metric for student success and retention [15-17]. Wilcox also showed that after completing their first computer science course, students with previous programming experience had higher retention rates than those without [18]. Given the diversity of our freshmen engineering population, and our continuous retention struggle, we considered an intentional approach to implementing the SI program in fall 2020 that could directly improve GPAs and therefore potentially impact a student's decision to stay within engineering.

Results from multiple studies revealed that session attendance positively impacted exam scores, overall course grades and DFQW (Ds, Fs, Q-drops, Withdraws) rates [3, 4, 19, 20]. This research has shown that regular attendance (i.e. attending six sessions or more) has the highest impact on grade outcomes, retention and graduation rates. Some works have sought to determine factors that influence attendance in optional SI sessions, by using qualitative data on students' attitudes and perceptions of SI and it's benefits. Some findings were that trusted individuals' (close peers, influential faculty, parents) promotion of SI sessions predicted attendance and students exhibited preferences for expert one-to-one (e.g. office hours) over one-to-many (e.g. SI sessions) supports, as well as preferring group study opportunities to be self-created [21, 22].

One of the most important components of the SI model is voluntary attendance. SI sessions being optional, assigned to historically difficult courses, and open to all students could entice a variety of students to attend. This potentially creates a safe learning environment with a diverse pool of knowledge for each student to leverage in the co-construction of their shared understanding and application of complex content. However, as mentioned earlier, SI session attendance has remained low at our university. Previous surveys conducted by this research team have demonstrated that many students do not have a clear understanding of what SI sessions entail and therefore choose not to attend. Furthermore, students who do attend can be resistant to the components of the traditional SI model, such as active learning and collaborative group activities, so after a few sessions they choose not to return. This creates a tension with what has been shown in numerous studies [1]-[5], which is that SI's use of active and collaborative techniques promotes the social interaction that improves learning and retention.

The researchers questioned whether a balance could be struck between requiring regular attendance to SI sessions, while still maintaining student autonomy and positive perceptions of SI as academic support for all. For this reason, a cohort-based model was used where students interested in participating in the SI program signed-up for these sessions with limited seats in the first two weeks of the semester, with the understanding that they were highly encouraged to attend that session each week for the entire semester. This ensured the voluntary nature of student participation, while also establishing a peer group for students which could serve to enhance their sense of connectedness to their classmates. This report investigates the potential quantitative and qualitative impact of implementing this registration-based cohort model to SI

sessions. We hope to use our findings to better address the needs of the student population and to promote attendance in SI sessions as an effective intervention to address retention and success rates.

II. Limitations of Study

While the pilot course had about 180 enrolled students in the fall semester, limiting the session size (12 students per session, with 9 total sessions offered) meant that not all students would be able to register for and have a seat in SI sessions. Our previous data justified this decision, as the number of seats offered in the cohort based model (108) would be more than the attendance we normally garner in past semesters, when SI attendance had an attend-as-desired optional model.

One limitation of determining correlations between grade outcomes and SI session attendance exists due to the potential self-selection bias of student attendees. By using previous programming experience as a baseline, we can more accurately compare similar students to see the effects of SI session attendance. However, there are many confounding factors that could impact grade outcomes, such as students' prior and current educational experiences, inequities in investment and resources in prior educational institutions, variations in help-seeking behaviors, intrinsic and extrinsic motivation and mindset. All of these factors and others make correlating student performance to SI session attendance difficult.

In an effort to more accurately determine the impact of SI session attendance on grade outcomes, it is helpful to have some metric to compare similar students in the two groups. However, as freshmen, these students do not yet have college course outcomes that can be utilized and the researchers had limited access to students' high school coursework or college application information that would report such helpful metrics. Therefore, we used self-reported data on their previous programming experience, collected via a survey conducted at the beginning of the semester. This data could be seen as subjective, but it is the most equitable metric we could collect and use for comparison.

Another limitation with respect to the qualitative data was the number of interviewees we were able to recruit. While we had 103 students who attended at least one SI session, only 8 students responded to the email request to be interviewed. Our methodology of drawing out emergent themes that are common amongst all the interviews help report SI session attendees' common experiences. Thus, our qualitative interview data may not encompass all SI session attendees' experiences but we expect it's a representative view of those who regularly attended SI sessions.

III. Definitions Used in Study

The following terms utilized in this study are defined according to the authors' and the university's use:

- Q-Drop: students may leave a course after the 12th class day with a "Q" noted on their transcript [17].
- QDFW% rates: the percentage of students in the course who Q-dropped the class, made a D, F, or withdrew (and received a W on their transcript), in comparison to the whole student population for that course.

- "SI" students: students who attended 6 or more sessions
- "non-SI" students: students who attended 5 or fewer sessions.

IV. Research Questions

To assess the impact of SI on freshmen engineering participants, this report addresses the following questions:

1. How did SI attendance affect overall course GPAs for SI students versus non-SI students in this course?
2. How did SI attendance affect QDFW% rates for SI students versus non-SI students in this course?
3. Did having students register for the same SI Session and "requiring" attendance to that same session affect attendance trends and therefore overall course GPAs and QDFW rates for SI students, as compared to previous semesters where attendance was completely voluntary?
4. What were SI students' perceptions of the registration approach and cohort-based SI sessions?

V. Design and Implementation

Our design and implementation of the SI program in this engineering course in fall 2020 followed the traditional model, with a few adjustments. The first logistical step was to determine the number of sessions for which we would allow students to register and the number of seats we would set for each session. As mentioned in the Limitations section, we limited the session size to 12 students per session, with each SI Leader offering 3 identical sessions each week, for a total of 9 available sessions and 108 available seats. While this meant not all students would be able to register for and have a seat in SI sessions, 108 unique students were more than we had captured in past semesters' optional attendance offering.

We recruited, hired and trained three undergraduate upper-class EEC students as SI Leaders to conduct three identical SI sessions each week, using active and collaborative learning strategies. The SI Coordinator provided twelve hours of pre-service training for SI Leaders and then weekly training and development meetings (about one hour a week). Pre-semester training had two installments; the first was a Canvas module that required Leaders to work through three hours of asynchronous learning activities, such as an introduction to the SI model, lesson planning, facilitation techniques and marketing strategies; the other was two synchronous Zoom meetings with other SI Leaders and the Coordinators, to practice lesson planning, facilitation and discipline-specific discussions. On the second day of synchronous training, the SI Coordinator conducted an interactive presentation on community-building which provided examples, had SI Leaders generate ice-breaker and community building activities which could be implemented in sessions, as well as practicing these activities in their discipline-specific groups.

The next component was integrating the use of community building strategies in the SI Leaders' lesson plans. Leaders create their lesson plans the week before conducting sessions and submit them to their graduate supervisor or SI Coordinator for feedback and revision. The lesson plan template for fall 2020 was edited to include a section where the SI Leaders were required to

detail and describe the community-building strategy they chose to use that week. As each session had the same cohort of students, the SI Leaders were able to conduct activities that went beyond the superficial icebreaker and develop a cohesive community within each cohort.

We determined that limiting the number of students to 12 per session would be necessary to our community-building interventions, as well as help with several logistical concerns. Using the Learning Center's workshop registration system, we titled each session with the name of the SI Leader, the days and time of the session and the following description: "When you sign up for this session, you will be registered for this session for the rest of the semester and we highly encourage you to attend this session every Monday from 1-2 PM. If you miss three sessions in a row, you will be removed from the list and students on the waitlist will be added." After the first two weeks of classes was concluded and no more students were attempting to register, the SI Coordinator collated the rosters.

The rosters were shared with the SI Leaders, so they could use it to track students' attendance to SI, but also as one of multiple metrics of students' progress and overall state of well-being. Student attendance to SI sessions was used in combination with attendance in lecture, recitation, office hours, assignment completion and performance on quizzes. A scaffolded approach was developed for the team; absences from SI sessions would prompt an initial email communication from the SI Leader (a peer) and if other absences, missed/late assignments or concerns about students were identified, the instructor would reach out for ongoing check-ins. This allowed for a more holistic approach to faculty-student and SI Leader-student interactions, both inside and outside the sessions.

Weekly meetings provided the SI Leaders with ongoing practice of facilitation skills, SI strategies, discussion of pedagogy and theory and continuous feedback. During weekly meetings, the SI Coordinator conducted examples of community-building activities with the SI Leaders. This had a two-fold effect; it helped foster a sense of community and camaraderie amongst the SI Leaders themselves, and also demonstrated the practical application of these community building activities. The SI Coordinator often facilitated meta-conversations with the Leaders after the implementation of the activity, directing their attention to the components of the activities and as a team, they generated thoughts on their effectiveness, as well as how they could be altered for the needs of the students, or for the time of the semester. The SI Coordinator set aside time to check in about the community-building activities and any difficulties or issues implementing them.

VI. Methodology

This study will utilize a mixed-methods approach, incorporating quantitative data relating to grades and SI session attendance, with qualitative data relating to student perceptions of the cohort-based model of SI sessions.

Three forms of quantitative data were collected:
1. SI session attendance: SI Leaders downloaded usage reports via Zoom that listed student IDs and number of minutes of attendance for each session.
2. Grade Data: course letter grades and GPAs for all students enrolled in the course were collected. To examine the effects of SI on student academic performance, course grades

were converted from nominal to ordinal data as per the university's numerical grade point equivalents.

3. Previous programming experience: The faculty member administered a survey via Canvas, where students self-reported the level of previous programming experience, which was later divided into three categories - no experience, some experience and advanced experience.

Two forms of qualitative data were collected:

1. End of semester surveys: the survey was administered via Qualtrics to all enrolled students in fall 2020. It collected students' names and university identifier numbers (voluntarily self-entered) and then branched according to self-reported attendance to SI sessions. Students who attended SI sessions were asked to rate several aspects of the program, including the SI leaders, the group work model, and perceived benefits of SI sessions.

2. Small group/one-on-one interviews: the SI Coordinator emailed all students registered for SI sessions, to recruit volunteers to answer 7-8 questions about their SI experiences. The interviews were conducted by the SI Coordinator via Zoom and recorded. The recording file was maintained behind a university fire wall for security purposes. The program generated a transcript from which all student information was redacted, and this was used to extract emerging themes. The interview questions can be found in Appendix A.

VII. Findings

The data in Figure 1 shows a statistically significant difference in course GPAs for the "SI" group vs the "non-SI" group for both semesters (fall 2020 and fall 2019). Similarly, we see a smaller percentage of D's, F's, Q's and W's for the SI group vs the non-SI group for both semesters in Figure 2. However, the DFWQ rate is much smaller for both the SI and non-SI groups in fall 2020 compared to fall 2019 (2.8% vs 8.2% in Fall 2020, 9.1% vs. 22.7% in Fall 2019).

One criticism of accurately determining the impact of a voluntary support program like SI is the difficulty in extricating any self-selection bias. Theoretically, highly prepared freshmen whether they use or do not make use of academic support, may still perform well in the course and therefore negate the impact of SI. Using prior programming experience as a measure, all enrolled students in the course were divided into three categories (no experience, some experience, advanced experience) to then compare SI and non-SI students' course GPAs.

We performed a two tailed t-test with unequal variances on the averages of course GPAs for both the "SI" and "non SI" groups within each category of previous programming experience, as these populations were uneven in sample size and variances were unknown. The standard p-value indicating significance was considered <0.05 and if so, the null hypothesis (that any difference in the average course GPAs between the "SI" and "non-SI" groups was by chance) would be rejected. While the "SI" groups outperformed the "non-SI" groups in all three categories, Figure 3 shows a statistically significant higher GPA (p-value =0.038) for the "SI group" with no previous programming experience vs the similar "non-SI" group.
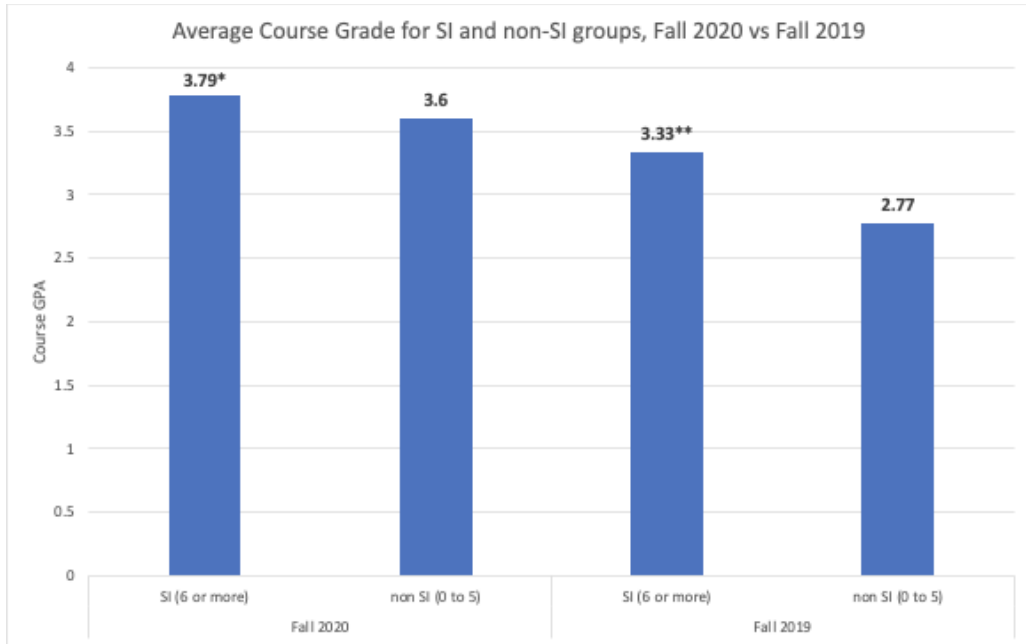
Figure 1: Average Course GPA for "SI" and "non-SI" groups, Fall 2020 vs Fall 2019
* indicates Fall 2020 t-test p value = 0.038 (statistically significant)
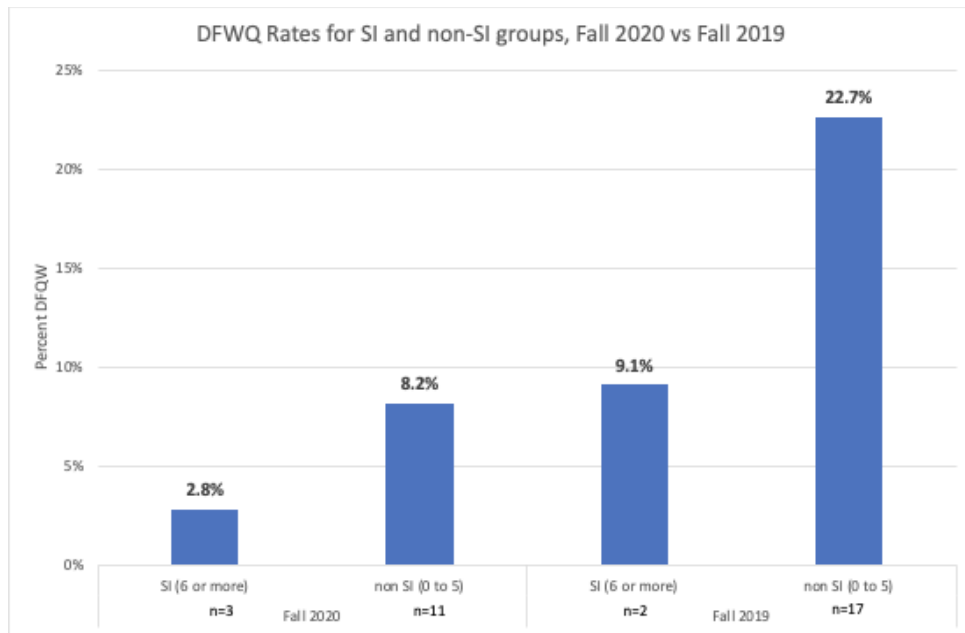** indicates Fall 2019 t-test p value = 0.015 (statistically significant)

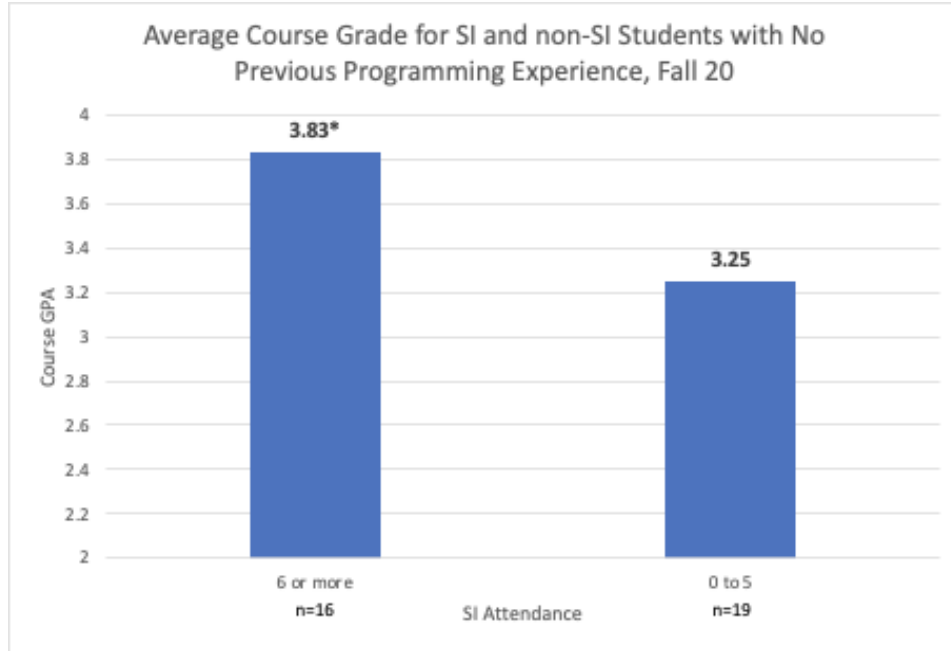Figure 2: DFWQ rates for "SI" and "non-SI" groups, Fall 2020 vs Fall 2019

Figure 3: Average Course GPA for "SI" and "non-SI" groups with No Previous Programming Experience, Fall 2020
* indicates t-test p value = 0.032 (statistically significant)
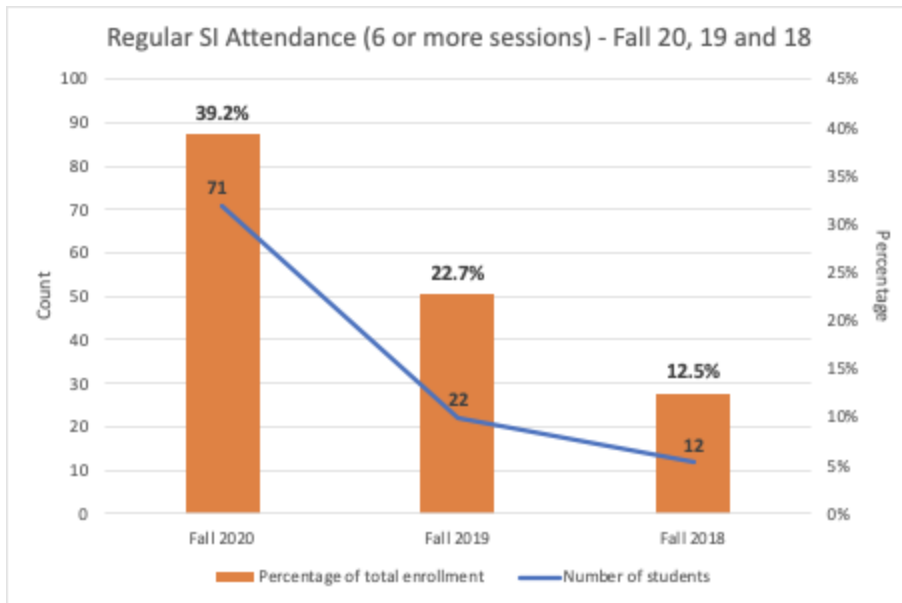

Figure 4: Percentage and Number of Students with Regular Attendance to SI Sessions (6 or more)
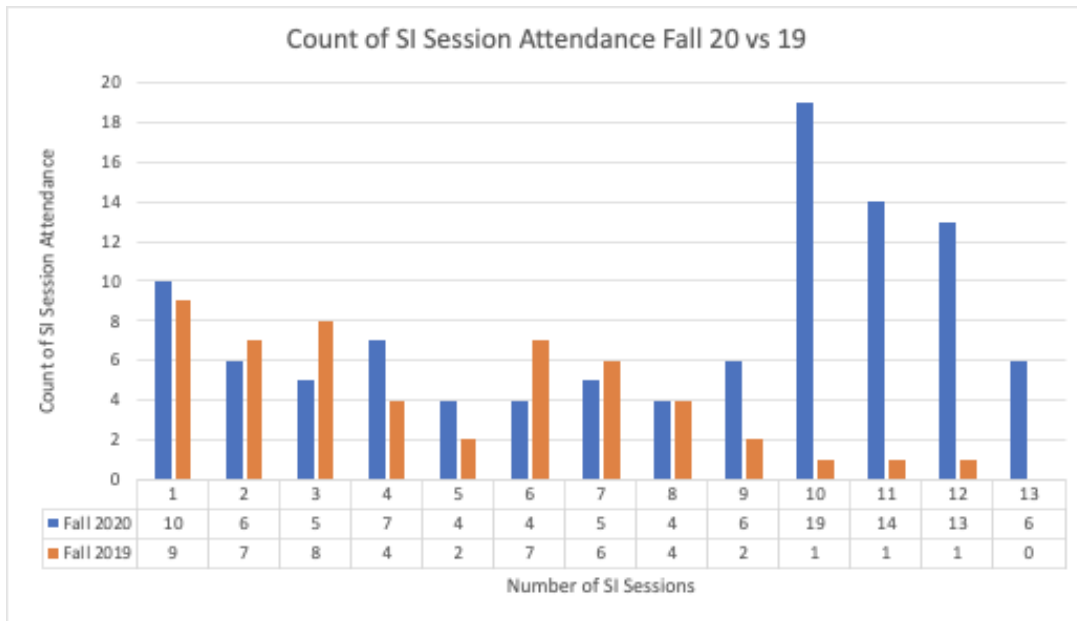Fall 2020, Fall 2019, Fall 2018

Figure 5: Count of SI Session Attendance in Fall 2020 vs Fall 2019

Figure 4 displays the percentage and count of students who regularly attended (6 or more) SI sessions, comparing fall 2020, fall 2019 and fall 2018. We see that fall 2020 has the highest percentage and number of regular attendees, with close to 40% of enrolled students attending regularly, compared to 22% in fall 2019 and 12% in fall 2018. Figure 5 shows the count of students that attended a certain number of SI sessions, in both fall 2019 and fall 2020. In fall 2019, 9 students attended only one session and the count for 6 sessions was only 7 students. One or two students attended 9 or more sessions and no students attended all 13 offered SI sessions. In contrast, 19 students attended 10 sessions, 14 students attended 11 sessions and 13 students attended 12 sessions, with 6 students attending all 13 offered SI sessions in Fall 2020.

To address our fourth research question (What were SI students' perceptions of the registration approach and cohort-based SI sessions?), we reviewed answers from the end of semester survey administered in fall 2020, and compared the fall 2019 data survey responses from the same questions. Results of the survey can be seen in Table 1 and Figure 6. When asked if they were happy with their grade in E E 306, 80% of respondents in fall 2020 answered yes, compared to 32.2% in fall 2019. When asked if they would recommend E E 306 SI sessions to a friend, 100% of fall 2020 respondents said yes (Table 1).

We see that 88 percent of respondents agreed or strongly agreed that "As a result of attending E E 306 SI sessions, my understanding of the course material improved", "As a result of attending E E 306 SI sessions, I feel more confident in my ability to prepare for E E 306 assignments and/or exams", "As a result of attending E E 306 SI sessions, I feel more confident in solving problems on my own" and "The SI Leader was knowledgeable about the E E 306 content". Other questions also garnered an overall positive response (majority of respondents), where 55% of respondents agreed or strongly agreed that "E E 306 SI sessions have increased the "sense of community" within the class and/or my academic program".

	Semester	
Question	Fall 20 (n =26)	Fall 19 (n =32)
Are you happy with your grade in E E 306? (Y/N)	80% vs 15%	32.2% vs 42.4%
Would you recommend going to an E E 306 SI session to a friend? (Y/N)	100% vs 0%	96.9% vs 3.1%

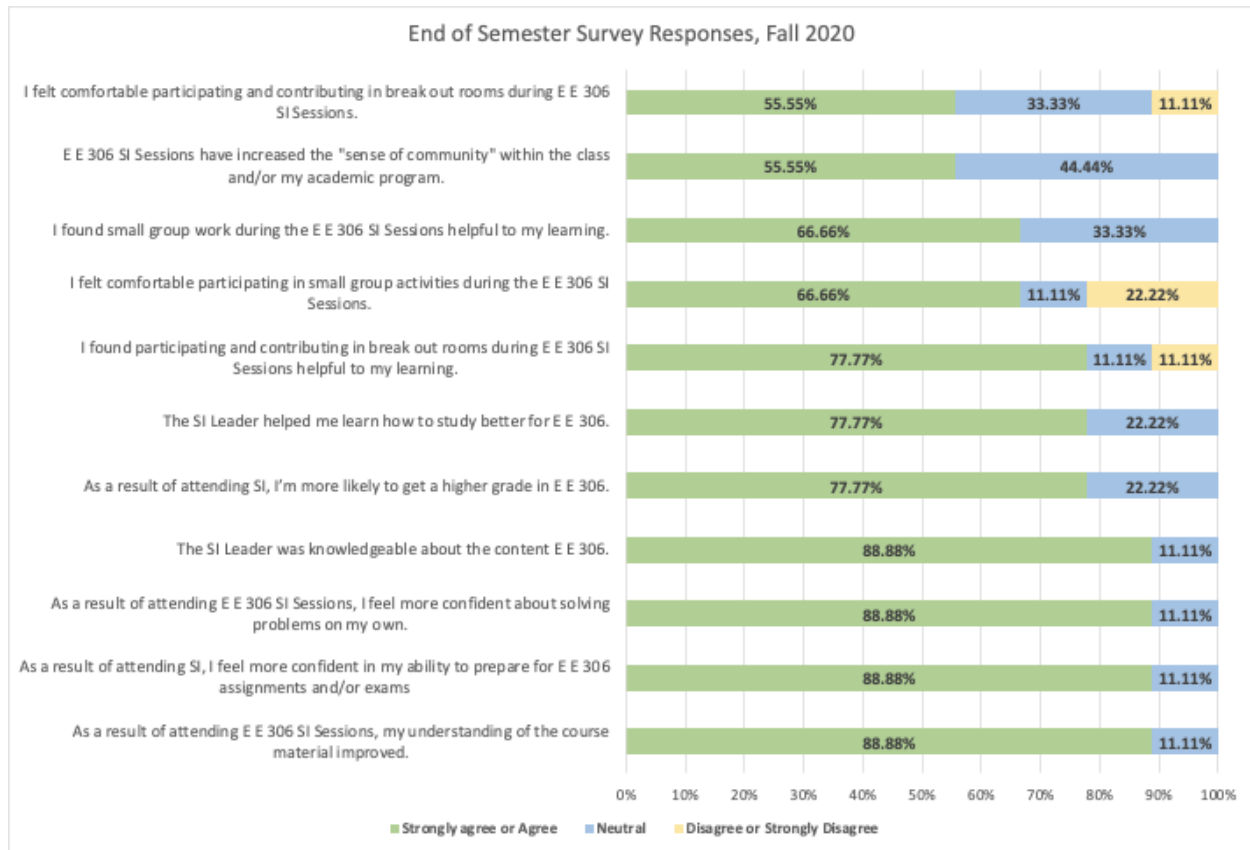Table 1: End of Semester Survey Responses, Fall 2020 vs Fall 2019

Figure 6: End of Semester Survey Responses, Fall 2020

Review of the six interview transcripts, which included responses from eight students, revealed about eight common themes. The emerging themes are: 1. Impact of knowing/having the same peers in sessions each week; 2. Impact of the SI Leader; 3. Accurate understanding of SI as a different type of learning environment with diversity in learning activities; 4. Perceptions of small group work; 5. Perceptions of initial email and ongoing communications; 6. Perceptions of being required to attend sessions regularly; 7. Translating SI activities/changing study strategies to own learning; 8. Impact of the demographics of the group or SI Leader. We will report examples of responses that could contribute or detract from our hypotheses on how the components of the registration, cohort-based approach implemented this semester impacted

students' course outcomes and retention. These themes will be connected to the research questions in the Discussion section.

1. Impact of knowing/having the same peers in sessions each week:

Almost all student interviewees mentioned the impact of having the same peers in their regularly scheduled SI sessions each week. We saw most respondents reported an increased sense of comfort with asking questions, working on activities and even a blossoming sense of community and friendship within this theme. It is also important to point out that most interviewees made comments about this sense of comfort increasing over time.

Positive:
- "I think one thing that really helped me learn was that I would see the same people every week."
- "I think that's the only place I tried out answers...it's not just me, like other people like, like as, as the SI sessions progressed, our group of people started to partake, participate more."
- "And so I guess I would feel more...open to asking questions in that environment."
- "I guess we all felt an obligation to contribute to like, a group activity in our small groups because we know like, we knew that we would see each other every week."
- "Not only, like, especially during the like, this time of Covid, we were able to like, kind of interact with others virtually. And we're also like, able to have fun with it as well."
- "I felt even more comfortable asking questions and clarifying things so, I guess the size of the group was probably helpful."
- "...so like, I feel like everything was very positive and like it was a good environment, good learning environment."
- "Yeah, I feel like that definitely helped...seeing the same names, same faces. Yeah, it even helps whenever people have their cameras on just because, like, "Oh, I like I recognize you" or like, so then it just makes me feel more comfortable like talking to them, I guess. So I did like knowing everyone in there."

Negative:
- "Kind of? I mean I don't know. I still really don't talk to them. So I guess it didn't make that big of an impact to me.**"**

2. Impact of SI Leader:

We saw an extremely positive trend in what interviewees shared about their SI Leader. Respondents generally found their SI Leader to be very responsive and helpful (not only about the course content but about other coursework and the engineering program), creating a safe and comfortable environment that did not stigmatize mistake-making. Some students even used the word "mentor", which they found extremely beneficial.

Positive:
- "...she would be like if you have any questions about anything, feel free to ask me, and at the beginning of class, she would do that too...she was like, "I'm open to questions about like, professors and stuff...so yeah, she, it was like I felt like, sort of like, like a mentor

relationship, but also like we knew that she was an upperclassman and we could ask her any questions we had about like courses to come and everything."

- "...our SI leader would also like, join in on the joke maybe a little bit...It felt like she wasn't like, portraying herself as like, superior to all of us, but like, also like, trying to like, she kind of conveyed that she wanted to help us, and she was, she was also a student like us, it kind of got us to be more comfortable."
- "...whenever he would ask questions like, he was really just, he was looking for an answer, not, not even the right answer all the time. He just wanted to see what we were thinking so then from there, he could explain to us, like why that was the right answer, or why it wasn't or even if it was the right answer, he would have us explain our thought process. So I always felt like that was a good thing because even if you did say the wrong answer, he would tell you the right answer and explain it to you. So that made me feel more comfortable answering, even if I wasn't 100% sure."
- "So let's say...he asks a question and I attempt an answer and I get it wrong...he'll be pretty encouraging in a way that's like, he, he won't be like, that's wrong. Or like, no. He'll be like that's partially right or like he'll point out something positive, or he'll be like, that's not the direction, or the answer I'm looking for something, that just that doesn't make you feel bad."

Negative:
- "I think my SI leader or was, I think they tried to answer...my questions more, but I guess like for lack of time and things kind of got a little rushed so...but I guess the person who was running the SI, like they were okay with answering my questions."

3. **Accurate understanding of SI as a different type of learning environment with diversity in learning activities:**

As mentioned in the introduction and motivation for this study, SI is often misunderstood by students as another recitation/discussion session, or another time for unidirectional delivery of information. Rather, we saw that most of the interviewees were able to distinguish that SI sessions incorporated engaging activities that helped them process the content again, in an alternative way to other learning environments.

Positive:
- "...the activities that were used to learn in SI sessions were a lot more diverse and I think, maybe even more helpful in that way."
- "Just looking at code on paper and just seeing if it'll work before I put it into...the machine itself to see if it will run. Um, and so yeah that activity helps a lot."
- "...she also did a lot of like, Kahoots and like games and stuff...And that really helped because they usually spanned over a lot of different topics, not just really focus on one and they would sometimes focus on details that I would forget. Um, so yeah, just those activities helped a lot."
- "SI Sessions were just really helpful for me. Because they provided...a different perspective from that being taught in like lectures and recitations."
- "I felt like the SI sessions were really enjoyable, like they were really fun because we did many. So like, umm like the SI leader was like there with you."

- "I guess examples, and I like drawing out like, what's going on. I guess being able to break the topic down like, into really small, like steps that are making that make it easier to understand."

Negative
- "...when I went to the SI sessions which, like the TAs, they were kind of drawing it out and going through like the steps...I think I'm basing, I will say, that they went like a little bit too fast for my taste."

4. Perceptions of small group work:

A consistent focus in SI is highly encouraging students to work in small groups on the planned and structured learning activities within the SI sessions. This team has seen resistance from students on participating in small group work during in-person sessions, so we were even more concerned that an online version of SI would yield more apathy and lowered engagement in said activities. We saw a generally positive response to the small group work, and the use of breakout rooms in Zoom assisted in encouraging students to work together.

Positive:
- **"**we're not just going to be there working on problems, like the whole one hour. We're also gonna be like having fun as we do it."
- "...our SI leader, would just...tell us before we went to break out rooms like okay "we're gonna give you like each program, we're gonna have y'all code it and then I'll be reviewing it" and stuff like that. So when, once we got into the breakout room, we could just...start attacking it straightaway."
- "I like that just because it's helpful just to like, feed off of, sometimes it would even just be like me and one other person in a breakout room and trying to figure out certain questions or whatever and just being able to talk about it and talk through it and if the other person would say something then, like I could even just ask, like, "wait, why would it be this and not this" and...that kind of thing. It just, so I like being in a small group because you can just have those discussions easier than having...people jump in and like I don't know it's just less confusion, I guess."
- "I was in a breakout room with someone, it was relatively small so you'd be in a breakout room with like one person. And if I was confused that person would try to help me understand, like clearly understand rather than giving me an answer, a direct answer they offer an explanation."

Negative:
- "I guess they were OK. But I will say the issue of being able to like, actually get to say something was sort of an issue for me because I was typically in a group with like people who were definitely pretty straight for on getting whatever it was done, but they didn't really do a good job of like trying to explain what was going on, when I asked.**"**
- "It might just be a group of like, a breakout room where people don't understand anything at all, they're just sitting there kind of confused. I think that'd be the only thing that might not, might not have helped with the group work."

5. Perceptions of initial email and ongoing communications:
The research team was curious about students' perception of the initial emails and communications about registering for SI sessions -- as we mentioned in the methodology, we phrased the emails with language that tried to convey the urgency to register (limited seats) but also tried to convey that attendance to the same session would be highly encouraged but not directly punitive to grades, with extended absences leading to their removal and addition of waitlisted students.

Positive:
- "I felt like the need to sign up for them right away because, um, well first, because like in the email it said that there were limited spots. And so I'm like okay yeah i need to do this but also because I had heard about them from Dr. Telang on because at the beginning of the semester, she was talking about how attending recitations and SI sessions were...crucial to doing well in the class...but I knew that they were important, but because ...I had heard it from Dr. Telang".
- "And the fact that I feel like the fact that you have to sign up for it, made it like better and more beneficial. Just because I felt like I needed to go because I'm signed up to be here and like, I need to take advantage of this."
- "...when I first saw the email, I think there was like, one line that was like, "Oh, there is like attendance to SI versus like grade." I think that thing. I think that was a big factor in a lot of people signing up, just because a lot of us are grade-oriented, but like when I saw it, I was like, okay, it can't hurt. It's just like another thing to go to and learn."
- "My reaction to emails from...my SI instructor...whenever I would see them, I was sure to click on them because I knew they were important...she made sure that if there was any like supplemental content that we needed, she would email us so if there were like PowerPoints. She recently sent us the link to the Kahoots, like the review Kahoot for the semester exam. So she, just like a lot of her emails were just very filled with like, that sort of content."
- "For 306, the communications was definitely like a good thing for me...And then it kind of just, it kind of showed that like, my professors and TAs cared about like how I did in this class. It wasn't just, "okay, here the assignments" and then they don't communicate anything between and they only care about when you turn in assignments...Oh, especially Dr Telang. She was really like out for like, mental health. So she would be posting like, "here's a museum tour like, here's like a good zoom lecture that's about mental health", and it was kind of like, it was nice because it kind of showed that like she cared a lot about like her not only like our grades, but also like or mental health and everything."

Negative:
- "So I had kind of, like a mixed reaction because like the first thought that came to my mind when I read the email was that it was mandatory because it kind of had like the mandatory vibe."
- "I feel like if, if anything, like, maybe just like advertising more so like, everyone understands...what SI is and how it can help you. And then...because then like it shows everyone...what SI really is and how it can help you and then it gives them a better like understanding of the choice they might make at the beginning of the semester, and then it,

because like at the beginning of semester, if you didn't register for a time, then you didn't really get like enough, you didn't really get an SI session later on. Maybe like they missed out on an opportunity. So maybe just like give everyone a better understanding or, like, how SI can help you and everything."

6. Perceptions of being required to attend SI sessions regularly:

Most SI sessions being optional and a come-and-go type of support, we were interested in learning students' perception of the "requirement" to attend the same SI session each week -- we were especially interested in seeing if students' felt deterred in any way to register due to the regular attendance requirement, and if they would consider it loss of flexibility and autonomy or a positive structure that promoted community and consistency.

Positive:
- "...it was something consistent in my schedule where I didn't really have to worry about it every week."
- "Luckily for me, like the one I signed up for at the beginning like, worked for me, time wise so I was like, I'm just going to attend every single one. Because like, it works for me. And it helps me like, learn better."
- "I think it made it easier because it gave me a more straightforward schedule."
- "I guess just, I thought it'd be a good thing to devote like an hour of time each week. And the fact that I feel like the fact that you have to sign up for it, made it like better and more beneficial. Just because I felt like I needed to go because I'm signed up to be here and like, I need to take advantage of this."
- "...even though if it's not mandatory...the SI session would...help me learn especially...in a virtual environment."
- "I didn't really have any particular reaction. It was more like I knew I was going to participate because, umm the most, the general consensus from upperclassmen is that use the resources given to you. And so I was like okay, resource. I'm definitely going to sign up. And Dr. Telang really encourages, like she encouraged students throughout the semester to attend recitations and SI sessions, both of them. And so I did. And I guess my process of joining was I looked at my calendar and...I picked a time slot."

Negative:
- "Yeah, when I initially saw that I was like "Oh geez." This is what, this might be a very like, "we're kind of required to go all of these" and then it was like it was registration, as well as, like, what if I don't get like, the time slot like that works for me? It was kind of a little like, weird and little like, I was kind of anxious…"

Neutral:
- "So I was just like, "eh I guess I'll sign up for it". I mean it wasn't a class, so I was just like, if I can't make it then I just don't go, oh, it's not going to have a big deal on me."

7. Translating SI activities/changing study strategies to own learning:

SI lesson plans make use of three branches of engagement; the students' interaction with the content (learning strategies), the students' interaction with the Leader (facilitation strategies) and

the students' interaction with each other (collaborative strategies). The learning strategies are ways that students can organize, process and apply their understanding of the content, and many programs posit that students' exposure to these strategies in SI sessions will help them internalize their benefits and explicitly apply them in their own private study time.

Positive:
- "That really helped me and I started doing that, like on my own. Just looking at code on paper and just seeing if it'll work before I put it into...the machine itself to see if it will run.
- "...we didn't really like explicitly learn study strategies but like I guess, working with other people and...explaining it to them like that made me realize you like, truly understand something when you try to explain it to someone. So just like when you're studying and seeing if you can...name all the steps in, or...explain it like thoroughly to someone who doesn't know what anything is."
- "...target like what you're not like, that good at. So, um, whenever I had to study for another class, I always check first, like what concepts do I like, not know really well. And then I would maybe like, pull up some problems from the textbook or maybe review the kind of the definitions or like vocabulary more and then that way, whenever I review, like the, all the concepts holistically. I'm able to connect the different topics together."
- "I feel like going to SI itself was one strategy, just like games like being able to go there and then retaining that information and then knowing that I can go to like office hours have some more help with another strategy."
- "I guess, working with other people and...explaining it to them like that made me realize you like truly understand something when you try to explain it to someone."

Negative:
- "I think the SI sessions made me kind of like, it made me mark down more things that I might want to review while I was studying, but that was just like content, while I don't think it actually changed my study habits."
- "I don't know, solving those type of problems...I'm just more the person who just reviews notes, that kind of thing. But I feel like that hour, doing different problems and stuff helped me but it didn't necessarily make me do, do that on my own...It was like that was my time to solve those kind of problems...I definitely feel like I could have (translated SI activities to my own study time) because we still...have access to, the most of the problems that they gave us. And so I could...go back and look over the problems again and, it was just more of like, that's just not my style of studying right then."
- "Dr. Telang would like post her weekly videos and so I'd watch those, take notes and then read the textbook and then by the time like I did all that, it was basically like the week was over, so I didn't really like re-study that."

8. Impact of demographics of the group or SI leader:

The logistics of the registration and cohort-based SI sessions did not include an intentional organization of the groups based on students' demographics or identities, but the collaborators were aware that the breakdown of the groups and/or the demographics of the Leader could have an impact and required investigation.

Positive:
- "I think our SI session group for 306 was pretty evenly split in terms of like, gender. Yeah, there was about, like, half of it was girls and half of those guys. And I think that helped me feel a lot more comfortable."
- "Yeah, I mean, like, even if I don't think it did, I think it did, like in reality. Because...in high school, I've had...a lot of like female teachers and usually they are like Asian or of like Asian ethnicity and so...I was like, really close to those teachers. And so I think like, going to college, I'm just like, more comfortable with sort of that group of like, instructors...But yeah, I think it definitely helped her, I was just more comfortable I think with her."
- "It was nice to see girls definitely would be weird or not weird. Just like I guess, I don't know. It's nice seeing girls, it is easier talking to girls, having that to relate to. I don't know. I heard that you like, get to basically know all the girls in ECE because there's so few."

Negative:
- "First off, I was, I think, pretty much the only girl in my SI session. And that was kind of like, I was expecting it, not like I'm not, I mean that's what some people would say, like, it's a male dominated field."
- "Yeah, like maybe in person like, a more representative demographic would be helpful to other people."

Neutral:
- I would say in terms of like, I think there was me and probably one other girl in there. And...that didn't impact me in any way because I'm kind of used to like, in all, almost all the classes in ECE, like there's typically more males in it...I don't know, I feel like that didn't affect me. But like you do, notice that there is less females in there. But other than that, not, that didn't, demographics didn't really impact me."
- "I mainly went for the learning experience. Anyway... I wasn't too bothered by it. Since it was online, I don't think I would have made any close friendships, either way if I'm being honest."

VIII. Discussion and Summary

In this complete research paper, we have outlined our methodology for implementing a registration cohort-based approach to SI sessions for E E 306, a first year engineering course and measuring the impacts to grade outcomes and students' perceptions of this model. As many studies have documented [2], [3], [4], [11], [12], the positive impacts to course grades tend to appear after students attended 6 SI sessions or more. However, it has been our experience that only a small number of students at our university will even attend 6 sessions, let alone more than that. Hodges et al. documented their success with requiring mandatory attendance to developmental mathematics SI sessions [23], so our research team attempted to create a registration approach that balanced strong encouragement for regular attendance but that was not directly punitive.

The average course GPAs were significantly higher and DFQW rates were lower for the SI group compared to the non-SI group this semester. Another positive outcome from requiring students to register for one session and highly encourage their attendance to that session was that we saw a large increase in the number of students who regularly attended SI (i.e. 6 or more sessions). We saw close to 40% of all enrolled students attend at least six sessions, with a large number of students who attended 10-13 sessions. As the SI program's effectiveness is assessed by improving outcomes and in turn retaining more students to the ECE program, we see this large reduction in the DFQW rates in this first year engineering course as vital.

Like many other staff and faculty at higher education institutions, the research collaborators were working within the parameters of completely virtual instruction, perpetuation of social and educational disparities and potential loss of community and connection. An online offering of this crucial course that covers a depth and breadth of programming content, can be challenging for all students but can especially halt minoritized students progress through their engineering coursework and ultimately prevent successful completion of the program. The common explanations of gender and racial disparities in STEM outcomes have shown to be unfounded [24]. These findings indicate that gender and race, as social constructs, are highly tied to social class and wealth, which can impact performance on standardized testing, school environments and resources, the STEM high school to college pipeline and eventual higher education persistence and matriculation.

This chapter reports, "the bulk of the research on course-taking disparities strongly implicates within-school sorting processes, such that Black and Hispanic youth are less likely to be enrolled in advanced courses compared to their White peers" [24]. Thus, we are aware that many of our students come to our university with likely low or no prior programming experience, by no fault of their own. To ensure that our SI program was not only assisting students who are already significantly resourced, we used students' self report on their level of prior programming experience to compare the impacts of SI session attendance. We were pleased to find that students with no programming experience who attended SI sessions significantly outperformed their comparable peers who did not attend SI sessions.

The qualitative data we collected and analyzed indicates that the registration and cohort model was overwhelmingly received as positive by the students who participated. The themes that emerged from participant interviews (see Findings section) can be effectively linked to the two components of interest to this team; impact to learning and impact to community/connectedness. We saw multiple interview responses showing that knowing and seeing the set number of peers in SI sessions each week created a more comfortable and fun learning environment. When asked about their impressions of the initial email communications that included language to encourage them to attend regularly, some students indicated that it initially felt mandatory, but many were made aware of the benefits and so regular attendance did not deter them from registering. Some respondents even mentioned that the structure and accountability of having the same session on their schedule eased their time management.

One common issue we've encountered in past years was a lack of understanding of SI, it's model and students' practical knowledge of what happens inside an SI session. Unfortunately, voluntary attendance can exacerbate this situation. Students who do attend can be unpleasantly surprised by the small group approach and especially freshmen students transitioning from high school learning can be resistant to the peer group work model and activities that require active processing and mistake-making. Students who never attend have no

framework from which to gauge the sessions and therefore are not aware of the potential benefits of attending. On the other hand, interviewees were able to accurately identify the diversity of activities in SI sessions and how different it was from other learning experiences, such as recitation or lecture. They were also able to speak to the fun games and engaging exercises that SI Leaders use in SI sessions.

The impact of the SI Leader cannot be understated; as the content expert, they must constantly strike a balance between assisting students, teaching students to learn from each other, promote self-directedness and develop community and connectedness. Many interviewees spoke about their excellent, helpful, compassionate and encouraging SI Leaders. SI Leaders created a safe and comfortable environment by incorporating community building activities and using language that ensured students felt no shame or stigma for the struggle associated with deep learning. The interviewees appeared to appreciate that while the Leader was a peer and therefore never claimed to be superior to the students, they could act as a program mentor, providing advice and ideas to students about future coursework and their academic program.

Both the demographics of the SI Leader and the peer cohort could be seen to anecdotally affect some participants. The negative effects seemed to be most pronounced among female students who had both a male SI Leader and a majority male cohort, whereas female students who had a female SI Leader and equally gendered cohort seemed to find more positives in the experience. Our university only collects binary gender markers, so in future, we hope to investigate more accurate measures of students' identities to better their SI experience.

Lastly, an important component of SI is students' observation of effective study skills within the SI sessions, which they can translate during their own study time. Our interview data did not yield as ubiquitous an experience for all SI students; about half the students were able to explore the techniques used in sessions and even identify why those techniques were effective and how to implement them on their own. The other half of the students seemed generally neutral to implementing SI techniques on their own; most claimed that attending the SI session itself was a form of strategy use and that the one hour SI session was their main opportunity for problem-solving and active learning each week.

Thus, we interpret our data to indicate that students who registered and regularly attended their cohort-based SI sessions developed a better sense of comfort and community, as well as opportunities to process and problem-solve in enjoyable and engaging ways. The obligatory language of initial sign up emails did not deter many students and was generally seen as a positive component that helped students stay accountable to the course and their peers. This contributed to improved quiz, lab and overall course grades, compared to those who did not attend SI. We are encouraged by these findings and detail our future plans with the SI program below.

IX. Future Research

The positive impact of SI program measured in the fall 2020 implementation of registration, cohort-based SI sessions on student performance and retention in a first year required engineering course has encouraged us to continue with this model in future semester offerings. In order to motivate more students to sign-up for SI sessions in future semesters, we plan to have multiple rounds of registration throughout the semester. The registrations will be timed according to the midterm exam and programming assignment schedule.

A more intentional effort will be made to not only focus on community building activities, but to form communities more carefully so as to have diverse groups of students represented in all group activities.

Another practice we can follow in future semesters to inspire more students to attend SI, is to invite past attendees to talk about their experiences with SI and how they benefited from attending sessions regularly. So far our marketing strategy for the SI program has included promotional materials and videos created by SI leaders. Having past SI program attendees also participate in these videos will also help garner more interest.

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Appendix A
SI Session Experience Interview Questions

1. Describe any positive learning experience and any negative learning experience that you've had?
Probe: How did that experience make you feel?

2. Thinking specifically about SI Sessions, what characteristics of this learning experience has helped you learn?
Probe: Comparing lecture, recitation sessions, office hours, etc., how have the activities in SI Sessions helped you learn?

3. How did you feel about the small group/ group-work aspect of SI Sessions?
Probe: How did you feel about the interaction with other classmates?
Probe: How did you feel about the interaction with the SI leader?
Probe: Do you feel this aspect was something that enhanced or detracted from your learning?

4. Thinking about the beginning of the semester, when you received the email or saw the announcement about SI Sessions, what was your initial reaction?
Probe: Did the announcement make it clear that "signing up" was for the same session each week, for the rest of the semester?
Probe: If so, how did "signing up" and scheduling the same session impact your intent to attend each week?
Probe: Were there weeks when attending the session you signed up for was inconvenient or conflicted with other priorities?

5. Thinking about the semester as a whole, did attending the same session with the same peers impact your interest to keep attending regularly?

6. You may have received email communication from your SI Leader, professor, TA, etc. throughout the semester. What was your reaction to those communications?

7. What kind of study strategies did you use in SI?
Probe: Did you translate any of the strategies you saw/used in SI when you studied on your own?

This concludes the interview. Do you have any questions you would like to ask? Do you have any further comments you would like to make regarding our discussion?

Thank you very much for participating in this discussion.