International Journal of Engineering Education Vol. 38, No. 5(B), pp. 1643–1659, 2022
Printed in Great Britain

0949-149X/91 $3.00+0.00

Engineering Students' Social Networks and Alters During the COVID-19 Pandemic*

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Social capital is essential to students' success and persistence in academic goals. However, during the period of emergency remote teaching brought on by the COVID-19 pandemic, students were isolated from their social networks. The purpose of this study was to examine how engineering students' social capital changed during the period of emergency remote teaching, looking closely at both the instrumental and expressive social capital from the people (alters) in students' social networks. We used an explanatory sequential mixed method approach that included collecting data from first-year students and capstone design students using the Undergraduate Support Survey and student interviews. We found differences between the types of alters that the two groups of students identified as influential to their success and persistence, including the groups of alters they identified (e.g., professors vs peers) and the length of relationship with their alters. We also present results from the interviews, highlighting examples of expressive and instrumental supports in both group before and during the pandemic. Overall, we found that the advanced students had more well-developed social networks than the first-year students to rely on during the transition. The first-year students, however, relied mostly on lifelong relationships. They did not have, and did not continue to develop, university-based social networks. We include examples of innovative ways that students maintained and strengthened their social networks and point to future implications of this work.

Keywords: social capital; emergency remote teaching; team-based learning; ALTERS, COVID-19

1. Introduction

The COVID-19 pandemic caused significant negative changes in social interactions. For example, one study of US adults reported significant decreases in both social network density and size [1]. These changes in social networks corresponded to increased loneliness, anxiety, boredom levels, as well as decreased motivation [2–5], especially for people who were cut off from face-to-face interactions with close ties.

For college students, the pandemic and the associated shift to emergency remote teaching (ERT) disrupted relationships with peers, instructors, and other campus contacts. Across the world, students were denied face-to-face interactions and many experienced changes in their financial or living situation that resulted in changes in their social relationships [6, 7]. About one third of US college students experienced changes in their living situations during the spring of 2020 [8]. Many daily and weekly interactions with university-based networks were eliminated, and some felt isolated and unable to interact in the ways to which they were accustomed.

Research conducted before the move to ERT suggests that students develop social networks which they rely on for support over the course of their education and that these networks are vital. Learning is a social activity in which students rely on engagement and interaction with others [9–11]. For example, engineering students rely on social interactions, such as talking to classmates about topics they do not understand and asking questions of instructors, to develop their understandings of new and complex ideas [12, 13]. When students have a strong support network, they not only learn more but are also more satisfied with their education and gain more resources from their education [13]. Thus, changes to students' social networks during the pandemic are of grave concern for engineering educators.

The goal of this paper is to better understand how engineering students' social capital changed during the time of ERT caused by the COVID-19 pandemic. Prior work has shown that students can have difficulty developing meaningful connections in online courses if social interactions are not explicitly planned for and developed [14, 15]. Institutions moved online suddenly during the spring of 2020 in response to the pandemic and instructors had little time to adjust their format for course delivery and had little knowledge or infrastructure related to support students online, which exacerbated the challenges of maintaining social supports.

In line with past engineering education research on the resources and support inherent in students' social networks, this study draws on the network theory of social capital [16, 17] and hence uses terms

* Accepted 16 May 2022.

from the theory. "Alters" are people within a student's network who provide support for their educational success and persistence. These alters may include a broad network of people both in and out of a student's institution as well as individuals they have known from other contexts. Alters provide social capital in the form of instrumental supports (tangible supports to achieve a specific goal), and expressive supports (emotional or moral support), and we refer to both in this study [17]. "Strong ties" refer to close relationships characterized by frequent, close contact such as those typically experienced with close friends and family and "weak ties" refer to relationships that are less frequent and close, such as those experienced with more casual acquaintances [18].

The goal of this paper is to understand how the alters in engineering students' social networks help them succeed in their coursework and major, and what type of social capital (instrumental or expressive) these alters provide. We address the following research questions:

1. Whom do undergraduates identify as providing resources and support important to their success and persistence in engineering?
2. How do instrumental and expressive social capital contribute to undergraduates' success and persistence in engineering?
3. How are the types of alters and associated social capital similar or different before and during the adoption of ERT in the COVID-19 pandemic?

2. Methods

This study uses an explanatory sequential mixed method approach [19]. The first phase consisted of the Undergraduate Support Survey (USS) and the second phase consisted of student interviews. We collected survey data from two groups of students at a large, public university in the United States during the final weeks of the Spring 2020 semester and conducted interviews with a sample of students from each group over the course of the following month. One group consisted of engineering students enrolled in an introductory, team-based engineering course with learning objectives focused on coding and engineering career development. Throughout the study we refer to this group of 92, of which 11 participated in interviews, as "introductory students." Ninety of the 92 introductory survey respondents and 9 of 11 interviewees were first year students. Two of the 92 introductory students who took the survey and 2 of the 11 interviewees, were in their second year. The other group of students were in their final year of an engineering technology degree and were enrolled in either of the two semesters of a team-and project-based, engineering technology capstone design course. We refer to this group of 41 as "advanced students"; eight participated in interviews. All had been enrolled at the university for three years or more. Both courses comprised students from multiple engineering and engineering technology majors working on interdisciplinary projects. Students' living situation information is reported in Table 1 and students' self-reported demographic information is presented in the appendix.

2.1 Quality Considerations

We collected and analyzed data consistent with the quality management process model developed by Walther et al. [20] to iteratively ensuring various aspects of validity. We use Walther and colleagues' terms "making the data" and "handling the data" to refer to these processes for each phase of the mixed methods project [20].

2.1.1 Making the Quantitative Data

The quantitative data consisted of survey responses

Table 1. Students' self-reported living situation during Emergency Remote Teaching

		Percent of introductory students	Percent of advanced students
Were you sheltering in place?	Yes	95%	95%
	No	5%	5%
Where were you sheltering in place?	Parent or family home	77%	39%
	My apartment/home	4%	39%
	A friend's home	4%	17%
	University dorm	6%	0%
	Fraternity/sorority house	0%	5%
	Other	4%	0%
With whom were you sheltering in place?	Family of origin	80%	40%
	Roommate	5%	25%
	Boyfriend/girlfriend/significant other	1%	18%
	By Myself	5%	18%
	Other	4%	0%

from 133 students across the two courses. We distributed the quantitative instrument, the Undergraduate Support Survey (USS), during the final two weeks of the spring 2020 semester. We compensated each survey participant with a $10 gift card.

We adapted the USS from earlier surveys used to study students' social capital [16], so that it would better align with the context of the shift to ERT. The survey included name generator and resource generator pieces designed to elicit strong and weak ties, respectively, though we took care to avoid social capital jargon in the participant-facing survey text. The survey had four sections: (1) open-ended questions about students' experiences during the transition to ERT, (2) name generator, (3) resource generator, and (4) demographic information. In Part 1, students were asked six questions: 1. How do you feel about courses being online during COVID-19? 2. What challenges have you had? 3. What are your experiences with your courses this semester? 4. Tell us about how your interactions with instructors have been during this time. 5. Tell us about how your interactions with other students have been during this time. 6. What, if any, positives have come about during this time of online instruction? In Part 2, we asked participants to list the names of up to five people they considered to be important for their success and persistence both overall and in the specific course, as well as specific questions about each alter they identified, including the length of the relationships, the age of the alter, and the preferred mode of communication. In Part 3, we provided descriptions of several types of support, such as "talked to me about their work as an engineer" and "helped me overcome an academic obstacle" and asked students to identify which alters from a list had supported them in these ways. Part 3 also included separate sections to identify alters who had provided participants with these supports before the pandemic and after its onset.

2.1.2 Handling the Quantitative Data

The quantitative data were analyzed in an iterative process. First, we cleaned the data by removing incomplete responses and organizing the data to be readable. Initially, we compiled and summarized the data using descriptive statistics to look for overall trends and patterns. We focused the analysis on the alter types and the relevant aspects of the alters. We then compared these trends to the qualitative data in an iterative process in conjunction with the qualitative analysis to select the more salient aspects of the quantitative data, specifically the types of alters students identified and the length of each of these relationships.

2.1.3 Making the Qualitative Data

The qualitative data used in this study consisted of 19 student interviews (11 introductory students and eight advanced students) conducted in summer 2020, immediately following the semester of ERT. Each interview lasted between 40 and 60 minutes and was conducted remotely via video call. The same researcher conducted all the interviews. Each student who participated in an interview had indicated they were interested in participating in the interview when they completed the USS. Students were compensated with a $25 gift card.

Our tailored interview guide used participants' individual survey responses to create an explicit link between the interview data and the survey data. The guide consisted of four sections, of which all but the first were tailored to individuals' survey responses: (1) establishing rapport and understanding participant's pandemic experiences, (2) follow-up to open-ended survey, (3) questions about each of the names the interviewee listed in the USS, (4) and questions about changes in resources interviewees listed in the USS. For the first part, we asked each participant the same basic questions about their experiences with ERT we had included in the survey, such as how they were doing, about their home/work situation, and generally how their experiences with online learning had been going. Follow up questions in Part 2 generally asked for more detail about topics interviewees mentioned in their open-ended survey responses, such as relationships they referenced or negative experiences during emergency remote teaching. For Part 3, we asked about each alter they listed in the name generator part of the survey, a specific time when the alter said or did something that helped the interviewee succeed or persist, what kinds of support that alter provided, and how their interactions and relationships with each alter changed during the pandemic. For Part 4, we asked for more detail about the specific alter types they had identified in the resource generator and how those supports had changed during ERT.

2.1.4 Handling the Qualitative Data

We coded the initial qualitative data analysis by coding each student interview transcript, identifying all examples of the student talking about their social capital. In this process we eliminated from consideration alters unrelated to the students' experiences at the university and their experiences during ERT, such as high school teachers and past internships coworkers with whom they had not maintained contact. For each example, we noted the type of alter providing the social capital, what kind of support the alter provided (instrumental or

expressive), and the timing of the example (before or during the pandemic or both). The list of types of alters came from prior work about salient alter types [17], which we then used to create the list of a priori codes for the survey. During the analysis, we added salient alter types that were not included in the initial list. The final list of alter types is as follows: university faculty, friends (peers that the students knew well), classmates (peers that the students only interacted with in class), family members, advisors, and teaching assistants (TAs).

One author did the primary coding of the data, interacting frequently with the other authors to discuss edge cases and questions that arose. After she coded the interviews, she compiled all examples into a single spreadsheet. She analyzed similarities and differences in participants' interactions with each alter type as well as changes in those interactions before and during the pandemic. The team iteratively compared those results with the quantitative results. We chose salient and representative examples for inclusion in the results section.

3. Findings

3.1 Survey Findings

In this section, we present the quantitative results for alters whom participants identified as being important to their success and persistence in their major. Fig. 1 shows the types of alters identified for each group; the introductory and advanced students. Results are shown as percentages of responses because each group had a different number of responses. The introductory level students identified that their primary social capital came from their friends and family members. This reflects their short time at the university (usually less than one year) and suggests they had not have developed strong ties with university-based alters before the move to ERT. Advanced students named professors as primary sources of social capital, and to a lesser extent their friends and family members. Advanced students more often named their advisors, and introductory students more often named teaching assistants as social capital alters.

The USS asked students to characterize the length of their relationship with each named alters. Fig. 2 shows these results. Introductory students relied heavily on alters they had known for one year or less, corresponding to their time at the university. On the other hand, advanced students relied on alters they had known for varied lengths of time, suggesting that they relied on alters they met throughout their time at the university. Both groups relied on alters they had known their whole lives – although introductory students relied on these more often – suggesting that advanced students were more independent from their lifelong connections.

3.2 Interview Findings

3.2.1 Alter 1: Professors

3.2.1.1 Before the Pandemic [Introductory Students]

Introductory students described receiving instrumental social capital from their professors before the pandemic. For example, professors gave students information during lectures about the course material and expectations, met with students after class to answer individual questions, and integrated applications of the course content that helped students understand why they were learning the course materials.

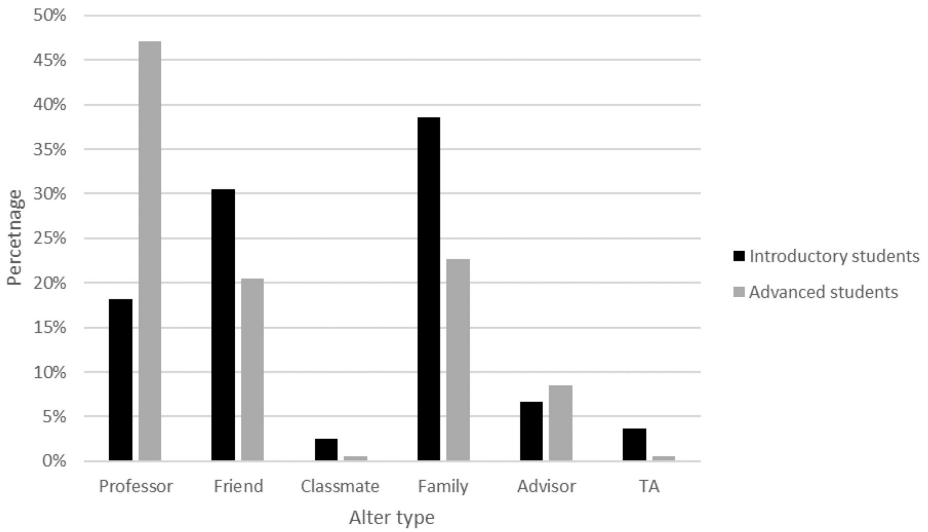

Fig. 1. Types of alters identified by each group. Represented as percentages of the total group.

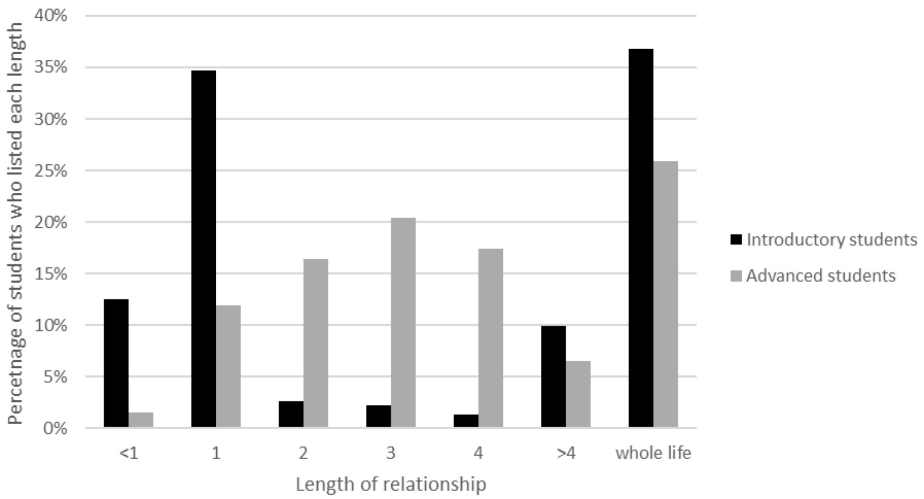

Fig. 2. Length of relationship with identified alters.

3.2.1.2. During the Pandemic [Introductory Students]

Students described how their professors continued to provide instrumental support during the pandemic, but the format of this support had changed with the initiation of ERT. Students described needing to take the initiative to ask questions, rather than listening to the responses from other students' questions in class. They viewed the loss of casual in-person interactions with their professor as a distinct loss of opportunities for instrumental support. In the absence of the direct, face-to-face interactions to which they had become accustomed before the pandemic, they found instrumental support via online meetings. They described how the instructor lectured and gave information to the students during online class sessions, frequent communication through email, and via the course communication platform. The students appreciated and credited the support they received in these formats with supporting their success in the course. For example, Student 4 said:

> "During . . . exams, [the instructor] was like, 'Look guys, I'm going to be on [the course communications platform] all the time answering your questions and making sure that the wording in the exam is clear and because if you're taking an exam you're kind of in the zone and you don't want to like get stuck on something and then have to wait like 20 minutes for response.' . . . She was really on it. So that was really cool."

This student expressed appreciation for the offer for immediate instrumental support when it might be needed. Student 15 also described that she found the live, instrumental support helpful:

> "We could just go into the [online breakout] room and have direct contact and conversation with all the TAs [teaching assistants], and our professor. . . . That was super helpful because I knew that there is a set time that I could rely on having those people to talk face-to-face . . . and also having my professor who just was doing nothing else but actively answering our questions during that time. So that was really helpful for me, because it's easier for me to articulate what I'm thinking in person and then actually talking than writing emails."

It was clear that live opportunities for instrumental support were vital. Online tools addressed some but not all of the limitations of not meeting in person.

3.2.1.3. Before Pandemic [Advanced Students]

The advanced students described receiving both instrumental and expressive supports from university faculty prior to the pandemic. Many advanced students described relationships with faculty members that had developed over the course of several years that included both formal interactions, such as course lectures, and informal interactions, such as during lab work time and in passing conversations in the halls.

Student 6 described vital instrumental support from a professor when they said:

> "I've had [the professor] three times now. . . he's one of the best professors I've ever had, awesome guy. He's somebody you can just go and talk to about his class or about another class because he used to teach some of the other classes in the major, so I would say he's been a pretty influential person in my major. . . . He knows a lot about the electrical engineering kind of space and . . . he was always available for questions."

Similarly, Student 9 referenced a professor who:

> "had always helped me with career advice and supported me throughout my interview process [for internships]. . . . He was there throughout all my interviews that I had for different companies and he would always listen . . . and kind of helped me to look at [my choices] and try to make a decision of what I really wanted to do. . . look at the different positions

> and see how his course would be beneficial in them. [There was a] lot of just in person communication. . . like in the hallway and [in] passing, but [during class] he always just came to my desk and would talk to me about it . . . or staying at the end of class . . . was always really helpful.''

Frequent, informal interactions even outside of class had been the means of providing vital instrumental support for Students 6 and 9. Advanced students also remembered receiving expressive support from professors before the pandemic. For example, Student 10 said:

> ''[My professor] was really, really nice. . . . One of my lab partner[s] was talking to me about [the pressure to be perfect as a woman in STEM] one day and she was getting really worked up. . . . And she went to the bathroom and she was gone for like 15 minutes and the professor came by and he was like 'Hey, is she OK?' and I was like, 'I don't know.' [He said] 'Well, if you want to go check on her you can, and like you guys can make this up whenever but I think her well-being is more important than this lab right now.' . . . That's a very nice, understanding thing to say. . . He was super nice and encouraging.''

This example rests on in-person interaction in various ways. First, a professor might observe that an online student in a breakout room has disappeared, but only through direct investigation. Further, Student 10 would have difficulty ''checking on'' the other student in an online format. This dynamic in which being told it was acceptable to offer expressive support to another student instead of prioritizing the lab work made Student 10 also feel supported is difficult to achieve through ERT.

3.2.1.4. During Pandemic [Advanced Students]

Overall advanced students felt that their relationships with their professors had changed since the onset of the pandemic, but there were exceptions. Student 10 described continuing support from a professor during the pandemic:

> ''My coding professor, she was the one who was always available to answer your questions, and she would check in on you and ask you how you were doing. And it seemed like she just actually cared about you and it's nice to see a woman professor who's made it this far in her field. She's definitely a role model for me. . . . [During the pandemic,] I would say she's still someone I look up to. And I probably talked to her more than any of my other professors during the pandemic because she had those live video labs and she utilized the video aspect of online learning a lot. So I was able to actually talk to her a lot during the pandemic and even one on one, because she had like the option where if you had a specific question, you could talk to only her and have her full attention.''

As this example suggests, synchronous meeting times were vital to expressive support. This student described how they were able to maintain relationships and still receive instrumental and expressive support from their professors during the pandemic through the use of live video interactions.

However, advanced students received support almost exclusively from professors teaching their current courses. Their relationships with professors whose classes they had taken in the past and with whom they had maintained relationships generally weakened during the pandemic. Speaking again of the professor she had three times and whom she described as an ''awesome guy,'' Student 6 said the following when asked how their relationship had changed since the pandemic:

> ''It's been pretty different I'd say. . . We didn't have really any conversations after spring break [was over, which aligned with the start of ERT]. . . . Part of it was I didn't really like necessarily need to have a conversation with him because there's other people that I could ask first.''

Student 6 did not name the loss of in-person interactions as playing a role. However, she mentioned talking about other classes with the professor, it seems likely she would have undertaken such conversations about her current classes, in normal times.

Student 7, on the other hand, felt that ERT had caused a material change in the nature of student-professor relationships:

> ''[I miss] just. . . developing good relationships with professors and just like, 'Hey how's your day?' and 'Oh, [how] are you kids doing?' You know, just the passing conversations or like quick questions. . . after class. It's a lot more intimidating to do that online and interrupt. [In person] at least you can raise your hand but you can't really do that online.''

Here, the student highlighted the limitations of online interactions and the resulting impact on relationships that might provide support.

3.2.2 Alter 2: Peers Before Pandemic [Introductory Students]

3.2.2.1. Peers 2a: Classmates, Before [Introductory Students]

Introductory students described receiving both instrumental and expressive support from their classmates before the pandemic. This support included help solving problems for the introductory course and understanding course material as well as emotional support to give them confidence about succeeding at the university generally. The fact that all students were taking team-based courses meant that they were interacting directly with classmates before and during the pandemic. Student 4 described how one of his assigned teammates helped him learn about future courses and related activities:

> "[My classmate is] already in [my engineering discipline]. . . . So he was really helpful in learning about what it's like later down the road as a sophomore. . . . He was really, really cool and always willing to help. . . . And he also told me about . . . solar racing [club] that he's participated in, he invited me."

This quote references instrumental support of various types the student received from a classmate.

3.2.2.2 Alter 2a: Classmates During [Introductory Students]

Most introductory students described continuing instrumental support and an increase in expressive support from classmates during the pandemic. Many of them credited this to the fact that their team project, which started at the same time as ERT, required more teamwork than previous assignments in the course. Student 4 described continued instrumental support he received:

> "Usually we would get on [a call] and just discuss what we had due just to make sure everyone was on the same page. . . . And then we would. . . send the [MATLAB] code back and forth and that was really, really helpful. . . . So, we were just online, kind of doing our own thing and then if someone had a question, we would answer it. So, it's just kind of chill and we would trade off, like if someone knew I was really good at plotting they'd be like, "Okay, send the code over I can deal with the plotting," and it was nice to have them online so you could talk about the variable names because its really hard reading someone else's code and then doing something with it."

This student described how, even though they were not in person, the teammates supported each other in their individual goals.

Student 15 described how her teammate helped keep her motivated when online learning got difficult:

> "It was getting a lot harder for us on online and [seeing my teammate] being able to do it . . . and showing me what she had done and how she'd done it. That was super helpful because I saw like "Oh, she's doing it. I can do it, want to do it, will be here for her, for my team, all of them." Just having [these] very smart and dedicated teammates was just a great thing that I very much needed."

Here, the student described how having the example of her teammates succeeding and having their support helped her to complete tasks and stay motivated.

However, not all students had this increased expressive support. For example, Student 18 said:

> "One thing I really liked about the first part of [the intro course] was how your group was more than just people you worked with on assignments and that you'd see each other on campus, which helps build . . . friendships, which makes your group work more comfortable. But then after the pandemic happened . . . the only times we talked to our group members is when we had talked to our group members to work on assignments. So, there was less of the feeling of camaraderie and that made group work kind of uncomfortable at times because we weren't really friends with each other."

This student felt the loss of in-person interactions strongly; friendships that had begun to build and enabled expressive support between teammates had dissipated.

3.2.2.3. Peers 2a: Classmates, Before [Advanced Students]

Like introductory students, advanced students described getting both instrumental and expressive support from their project teammates before the pandemic. For example, Student 7 described how a teammate had supported them in the course:

> "[My teammate is] really organized and really good about scheduling and making sure that we have all these tasks laid out and they know what needs to happen, which, I'm definitely the same way. . . . But also [because I'm new to this major, it also helped that] they've been in this major for the whole time and everyone else knew them on the team too and, just like, [they're] really charismatic and see[m] to know all the professors and all the people in the department. So they helped me in like in a lot of ways, for sure, just about, like, working with the team and dealing with different people. . . . [S]ometimes when I don't mesh with someone like that's harder for me and [my teammate] is really good about dealing with all kinds of people and kind of forming and understanding how they work."

Student 7 did not address whether the extensive instrumental and expressive their teammate provided depended on in-person interaction.

3.2.2.4. Peers 2a: Classmates, During [Advanced Students]

Most advanced students felt they received instrumental support from classmates. But unlike introductory students, the advanced students described disruptions to expressive support from classmates during the pandemic. For example, Student 6 described:

> "Basically what ended up happening [during the pandemic] was, our team only met when the professor scheduled a meeting. . . . Normally in class, when you would sit down with a group of friends or your team, you would have, like, some sort of just small talk, or like banter, but [now when] the meeting starts you don't have that at all. So, I was really good friends with a lot of people, I had really good conversations with a lot of these people in the group that weren't related at all to this class and it just felt like, I guess I couldn't have that once the class [went online]. What our group actually ended up doing, though, I think it was four weeks in, we did end up making a second meeting that started like 10 minutes after the first meeting so we could still have that good conversation and talk about other classes, too."

The initial move to ERT had disrupted expressive support, but the team had adjusted so that they could go back to providing such support.

Student 9 felt that online teaching had disrupted both instrumental support and expressive support. She explained:

> "So before the pandemic started it was an overall good team. We all met twice a week. We had a really good even distribution of work and really worked together when we were in person and like knew how to balance, who could do what [based on] what we're best at. [But] [d]uring online [class] one kid slept through most of [the team meetings] and then the other kid – [pause]. I felt weird asking them to like join the calls, because I was like trying to motivate everyone and nobody else wanted to do it."

For this student, even instrumental support had fallen away.

3.2.2.5 Peers 2: Friends Before [Introductory Students]

Students described relationships they had started to build with other students at the university, such as in their dormitories. Student 5 had received both instrumental and expressive supports from a suitemate he considered a friend:

> "He's one of my suite mates from [my dorm]. So we were both in the same learning community and we had to both go to those required classes. Anytime like, I had questions with [Intro to Engineering], I'd always ask him. He's helped me meet a lot of the people I know in the [learning community] now."

Answering Student 5's questions about coursework constitutes instrumental support; the suitemate's introducing Student 5 to others constituted expressive support. It was typical for introductory students to have at least some friends they had made in college who provided both instrumental support and expressive support.

3.2.2.6 Peers 2: Friends During [Introductory Students]

During the pandemic, introductory students continued to receive instrumental and expressive support from friends. For some students, typically those who had existing strong ties, these relationships continued to offer strong support. Some were described as strengthening during the pandemic because students had more free time. Strong ties that were developed either over longer periods of time (such as friends from high school who had also come to the university) or through multiple contexts (such as a student who was in the same dorm and in similar classes) offered the greatest support. For example, Student 5 described how his relationship with a close friend had grown stronger since the pandemic began:

> "[My friend] has always been there like to push me academically. I've known him since like seventh grade. . . . He is basically the one who pushed me to go take AP credits and do all the difficult classes with him. And that just sort of continued into college. So whenever I came to [University], we were still good friends, obviously, and he would continually encourage me whenever I needed help, or if I had questions. . . . He definitely just pushed me in general to be better. . . . He just came and stayed with me at my house after the pandemic for like two or three weeks."

For this student, instrumental support continued during the pandemic in much the same way that it had before the pandemic.

Student 17 described how their support from their friends shifted from mostly instrumental to mostly expressive:

> "We'd still call and we'd go on Snapchat. That was definitely still there, but it was less about school and [more just] about, 'How are you doing? How have you been? [Are] you keeping safe? What are you up to?' That was definitely like a weird adjustment to not be able to see them in person anymore and be able to hang out with them to just being by yourself pretty much all day long."

This quote describes the expressive support that friends gave each other during the pandemic.

However, for weaker ties between friends from friendships that were less developed when the pandemic started, the relationships and the supports they offered weakened during the pandemic. For example, Student 17 said:

> "When you're explaining something that you know but another person doesn't know, you understand that concept even better. When. . . you don't have any interactions with other students, you don't have those situations where you learn and they learn at the same time, it just really becomes a survival of the fittest kind of deal where everyone's on their own."

This student no longer had casual interactions with classmates from which they had previously derived instrumental support. Additionally, supports from weak ties remained almost entirely instrumental, perhaps because students did not have the casual, day-to-day interactions that could lead to more expressive supports.

3.2.2.7. Peers 2: Friends Before and During [Advanced Students]

Advanced students described their friends as vital for both instrumental and expressive support both before and during the pandemic. Often, these friends were also in their majors. For example, Student 7 said:

> "Yeah, so definitely my friends that I made [in my former major], we all share similar feelings of school is really hard and it takes its toll on everybody. . . . Making those connections [helped us] get through it together. Like, 'OK, I'm not alone.' [In my current

> major people] are willing to help each other. . . . People in this department . . . have had various experiences in different companies and co-ops and . . . we talk about it, what we liked and didn't like and why it would be helpful if you want to go on this path or why you shouldn't take this class, because the professor, like, just talks from their notes the whole time."

When asked if the camaraderie continued after the pandemic started, Student 7 said: "I'd say yes just, not as much obviously. . . . We're just not passing by each other. We're not walking around campus. We're not having events, it's just like, literally everything stopped existing." The pandemic had disrupted support but not eliminated it. Advanced students also described support from friends outside their major, largely expressive support. For example, Student 9 said:

> "I would say, the main thing about him [my friend] was, he was like my stress reliever and he was the person that was always telling me it was going to be okay and that I was going to graduate. So, when I had my problems and everything that happened with my teammate like, falling asleep or my [assigned project] mentor not caring, I would go to my friend and he would tell me it's going to be okay. Like, 'you're still going to graduate. . . You could do it. You're gonna get through it.' As well as also giving me advice on certain like [technical] things and talking about our projects together helped me with ideas."

Student 9 maintained contact with this friend even after the pandemic started. They stayed socially distant via video calls, online group chats, and even spoke from a distance from their neighboring apartment balconies. When asked if the relationship had changed since the pandemic started, Student 9 said:

> "I would feel like our interactions have actually increased since the pandemic, because we never used different forms of calling or Facetiming and we never had, like, a ton of group chats before the pandemic. But I think we both felt like really isolated in it. So doing that really helped us get out of it."

The advanced students retained strong ties with friends they had developed strong ties with over the course of their time at the university and received considerable support from these friends during the pandemic.

3.2.3 Alter 3: Teaching Assistants

3.2.3.1 TA before [Introductory Students]

Introductory students described receiving instrumental support from TAs before the pandemic, including help with homework and project problems and clarification of grading procedures. They also talked about having more casual conversations with these more advanced students about engineering in general during less busy times in class. For example, Student 4 said:

> "[The TAs] were mostly just like kind of like hanging out looking for people who had questions about MATLAB or whatever, but if I noticed they weren't really busy, I would ask them about classes they've taken. You know, like, they're all doing different [majors] and stuff like that. So I asked them about like classes they've liked, classes they didn't like."

This instrumental support went beyond what students needed in a particular course; Student 4 received information about course offerings and options at the university from TAs when they were able to interact with them in person.

3.2.3.2 Alter 3: TA during [Introductory Students]

During the pandemic, TAs continued to give introductory students instrumental support in response to specific questions. However, the format of this support had changed. It was largely given in breakout rooms for set periods of time and on online discussion boards. For example, student 14 described their interactions with the TAs during ERT:

> "[The TAs] were all on the Zoom calls that we had in the mornings. When we would go into our breakout rooms with our teams we could ask for help. And then it was probably one of the TAs that would come in and like answer questions. . . . it was a little different [than before ERT] because we didn't see them before they came to help us and they couldn't, like, try coding some things on our laptop to see if it worked or not, but they still were able to see our screen and give us some advice."

Similarly, Student 19 discussed how responsive the TAs were on the online discussion boards:

> "Like if somebody was studying for an exam and looked at an old exam question and they posted it on [the discussion board], the TAs would respond fairly quickly about how you do it. And step by step. . . It was kind of hard for them to like type it out and say, 'this is how you do it', versus like if somebody was in person, explaining it to you, but as far as like content based stuff, they were fairly good at explaining how you do stuff."

On the other hand, students did not describe any deeper level conversations with the TAs like those Student 4 described from before the pandemic. While TAs' instrumental support of students continued during the pandemic, it was not as comprehensive as it had been previously.

3.2.3.3. Alter 3: TA before [Advanced students]

Several advanced students described TAs who served as key role models and mentors for them, providing instrumental and expressive support, including specific help on assignments and discussing potential future career plans through sharing their own experiences. For example, Student 9 said:

> "[My TA] was always there and . . . helped me through my personal academic obstacles, [he would] look over

> my work as well as helped me to expand on ideas that I had. . . . [He was also] very helpful during the time where I was struggling to make career decisions. . . . He was getting his PhD and talking to him about potentially getting my master's degree eventually in the future was very helpful. . . I would see him every Friday this semester as well as seeing him every Friday last semester as well as seeing him in passing. . So even this semester. . . every time I saw him, we would talk about what he was doing and what I was doing. He was very pivotal in helping me to decide that I did want to get my masters' and to go into higher education eventually."

Student 9 also referenced receiving expressive support, what she termed "encouragement" from this TA. Similarly, Student 13 said:

> "At one point in the Fall or beginning of Spring I was questioning if I would like [my technical specialty] that much. If it . . . would get me into [the sector I want to be in] when I graduate. So it was kind of just me asking [my professor and TA] some questions like, 'Hey, if I don't get into this, what if I wanted to do [another job sector], is [my technical specialty] something that I could continue with or do I need to switch like into something else?' "

As advanced students in the same field, TAs were a key source of information about future careers.

3.2.3.4. Alter 3: TA during [Advanced students]

After the move to online learning, advanced students felt that they had suffered a significant loss because they did not have time with the TAs teaching their courses. Student 9 who had described her TA as "always there . . . help[ing] me through my personal academic obstacles" had completely lost this source of support. As she said:

> "My labs got canceled every week this semester during the pandemic. I went from seeing [my TA] actually quite a bit, because, as I said, [University Building] was like my second home and I was always on the [floor where]. . . his office was so [I used to see] him literally multiple times a week and then for like two hours during labs. [During the pandemic] I didn't really have like the guidance anymore. And like, the encouragement. So, I definitely would say the interactions went down a lot with the pandemic as well."

This loss was significant. It is also the case that, as an advanced student, Student 9 had already benefited a good deal from her TA's support, including setting her on a path to a particular career.

3.2.4 Alter 4: Academic Advisors

3.2.4.1 Academic Advisors Before [Introductory Students]

Introductory students had begun to receive instrumental support from their academic advisors before the pandemic. Advisors helped students find resources, plan coursework, and choose majors. For example, Student 14 said:

> "[My advisor] was just there if I needed help. One of the things that I like about him is that he helped me decide between [two majors] just by laying out a couple of different things about them, helping me choose what I like most about them. And then he also said that he would help me, this was pre-pandemic, that he said he would help me with this application for a scholarship, which was nice."

This student was able to sit down with their advisor and get this instrumental support that had been valuable.

3.2.4.2. Advisors during [Introductory Students]

During the pandemic, introductory students had much less interaction with their advisors; some described having none. For some students, this was because they had already made many of the required decisions about major choice as first year students and did not need as many formal meetings with their advisors. On the other hand, the online medium made interactions more difficult. For example, student 15 said:

> "We [video conference] called once, I believe, when course registrations and stuff were happening. But I would definitely email him at least once a week, once we were in the pandemic. It was a bit more sporadic because, well, first, I had answered a lot of my questions already, but then also, while at school I was also trying to figure out a lot of other things [about long term plans]. And when we switched to online that became very overwhelming. So, I was focusing mostly just on doing well in school, so I had less questions and less things to really figure out with him. We talked a lot less and also email is harder for me to really articulate what I need help with."

The pandemic had also led Student 15 to focus more on the classes that had changed because of the switch to ERT, rather than the longer-term plans that the advisor had helped with before the pandemic.

3.2.4.3 Advisors Before [Advanced Students]

Many advanced students described strong relationships with their academic advisors at the university that provided them with both instrumental and expressive supports. For example, Student 9 described some of the support she received from her advisor before the pandemic:

> "[My advisor] had helped me to pinpoint what I wanted to do as well as helping me achieve my dream of studying abroad and helping me get courses approved so that I had enough credit hours to, like, graduate. So having her on my team and always being willing to fill out recommendation forms for me really helped me to want to stay with my major. And she always just told me that I was doing really great."

Here, the student described instrumental support that her advisor provided in helping her manage the logistics of studying abroad and expressive support

by telling her to keep caring about her coursework. Student 6 also described receiving both instrumental and expressive support from his advisor:

> "I've had really good conversations with [my advisor]. I created a poster one time for a project. . . and she has it hanging up in her office. So, she's just someone I can go and talk to, and also she remembers things that you wouldn't think she'd remember. One time. . . [when] I shaved [my facial hair] she said, "Where's your beard?". . . Yeah, just a really all around nice advisor."

Here, the student described his advisor as someone he had known for several years and was someone on campus who cared about him, showed pride in his work, and noticed changes in his life, all examples of expressive support.

3.2.4.4. Advisors During [Advanced Students]

During the pandemic, the advanced students described maintaining relationships with their advisors. Most continued to receive both expressive and instrumental support. The advisors frequently reached out to students to check on them and continued to maintain the support, despite it being more difficult to connect with students over the online format. For example, Student 7 described how she continued to have both instrumental and expressive support from her advisor during the pandemic:

> "My advisor. . . she's awesome. She really made sure to keep in touch with me. And, you know, we'd have really long phone calls. And just about my future and stuff like that because you when I transferred into the program, I was just kind of like really frazzled. She's always been really helpful and after the pandemic [she continued] checking in on me and making sure, you know, if I need anything. And, like, also checking in to see if, like, [my summer internship company] had canceled their internship."

In such cases the relationship established before the pandemic seemed to enable their continuation with the move online, a benefit not observed among the introductory students.

At the same time, as with introductory students, there were advanced students who did not maintain communication with their advisors because they felt they did not need much in that period. Advanced students who were about to graduate and had their jobs already lined up before the pandemic felt they did not need much from their advisor during the pandemic. Student 9, who had received so much from her advisor, was among these students. However, social distancing also played a role in this loss of contact. As Student 9 said:

> "Since I was graduating [our communication] became less and less. [Before] usually I was in [university building] like all the time so I could just stop by and say hi to her. [During the pandemic] it just turned into not being able to see her or ask her any questions, not that I had that many questions [at the end of my] senior year, but it would have been nice [to have] face-to-face interaction to tell her what I was doing and where I was going. And she always kind of like served as the person that, like, I could complain to about my classes and I don't have that anymore."

This advanced student missed the expressive supports previously offered by her advisor but she did not feel she had a strong need for them.

3.2.5 Alter: Family

3.2.5.1 Family Before and During [Introductory Students]

Introductory students mentioned two groups of family members who were providing them social capital, parents and siblings. Parents provided primarily expressive support.

Most students stated that their relationships with their parents continued to remain strong during the pandemic and that they provided them with expressive support. The scant change in introductory students' relationships with their parents probably reflects the fact that both before and during the pandemic is likely because many were first year students who had only moved away from their parents' home recently. For example, Student 14 described their relationship regarding school with their parents before and during the pandemic:

> "[My parents are] just always really supportive on whatever I want to do. They always ask questions and make sure I understand what I'm talking about before I make any decisions, which is very helpful. If I need help with anything, they'll try to figure it out and help me. [During the pandemic] I got to see them now more than I would have had at school. So, they were definitely more available to me. They helped me keep a level head."

The main change in the relationship was that contact was more frequent, as students had moved back home.

Several students gave examples of receiving both instrumental and expressive support from siblings. They also reported minimal change, largely related to the pandemic. In Student 19's case, the pandemic brought him back together with a sibling who was older. Student 19 said:

> "My sister is an electrical engineering student in college right now. So she knows, kind of, what I've been going through; she knows about engineering courses. Seeing her [now that we're both living at home during the pandemic] and having her talk to me about different stuff, I would say definitely helped me say, 'OK, I want to be an engineer through all this.' . . . [My mom] of course is gonna be a supportive mother and say 'Do what you want to do.' I would say my sister has been more of a, 'Hey, be an engineer' kind of influence and my mom has been like, 'Hey, you can do it' type of influence. [I actually] feel like there's more of [these

Table 2. Summary of alters and example instrumental and expressive actions before and during the COVID-19 pandemic

	Introductory students		**Advanced Students**	
	Before	**During**	**Before**	**During**
1. Professors	Instrumental [engaging lectures that answered student questions].	Instrumental [offering rapid, live responses to questions via course communication platform].	Instrumental [helping to make decisions about internships]. Expressive [checking on well-being].	Instrumental [help with specific homework questions]. Expressive [checking on wellbeing].
2a. Peer: teammate	Instrumental [inviting teammate to get involved in co-curricular activities]. Expressive [helping with confidence to succeed in major].	Instrumental [strategizing team project task assignment]. Expressive [providing motivation for online learning].	Instrumental [organizing team project]. Expressive [friendly conversations and encouragement].	Instrumental [working on project together]. Expressive [creating extra meeting time to allow for chit chat].
2b. Peer: friend	Instrumental [answering questions about coursework]. Expressive [introducing friends to others with similar academic interests].	Instrumental [pushing each other be their best]. Expressive [checking on safety and well-being].	Instrumental [sharing professional and coursework-related advice]. Expressive [camaraderie via sharing experiences of difficulty in the curriculum].	Instrumental [few described]. Expressive [providing stress relief through active listening].
3. TA	Instrumental [answering questions about different courses, engineering fields].	Instrumental [answering to questions about coursework].	Instrumental [providing advice about career decisions]. Expressive [offering encouragement about academic obstacles].	Instrumental [none described]. Expressive [none described].
4. Advisor	Instrumental [assisting with scholarship application].	Instrumental [answering questions about registration].	Instrumental [helping with achieving goals such as study abroad]. Expressive [noticing changes in students' personal lives].	Instrumental [checking on internship status]. Expressive [reaching out to students to check on them].
5. Family	Expressive [parents providing encouragement that "you can do this"]. Instrumental [sibling offering advice about courses].	Expressive [parents providing encouragement that "you can do this"]. Instrumental [sibling offering advice about courses].	Expressive [parents asking about their well-being].	Expressive [parents asking about their well-being].

> conversations during the pandemic]. I guess because we're together."

For Student 19, his sister had provided instrumental support while his mother provided expressive support. The pandemic had increased this support because of proximity.

3.2.5.2. Alter: Family Before and During [Advanced Students]

Advanced students also maintained similar relationships with their parents during the pandemic, but in their case, for most, it was because they had stayed on or near campus instead of going home. All of these students had been living away from their parents for several years. For those who stayed near the university, their relationships with their parents continued to be primarily remote interactions that provided expressive support. For example, Student 13 said:

> "I haven't technically moved home in the last two years; I've been living on my own. So [my parents] just always ask how I'm doing. . . And then still, just like, me and my dad have a fishing trip that we schedule annually for every year. So I still get to go and have a little bit of fun with him."

Whether the pandemic changed familial relationships largely depended on whether students moved home. This is unsurprising given that many people continued to have face-to-face interactions with their family members.

3.3 Summary of Qualitative Findings

Table 2 summarizes our qualitative findings.

4. Discussion

4.1 Summary of Introductory Student Results: Quantitative and Qualitative

Overall, introductory students' networks were comprised primarily of alters with whom they had lifelong relationships and some alters with whom they had short-term relationships. For instance, when asked to identify significant alters, 39% identified family members, but only 18% identified professors. Similarly, 39% of the alters this group

identified were lifelong relationships and 34% and 13% were relationships that had lasted a year or less a year, respectively. This network structure is the result of the introductory students' short time at the university prior to the pandemic. As new college students, they still relied heavily on strong ties with family while developing weaker ties with campus alters. Interview data revealed that introductory students received that expressive supports from their family and long-term friends, such as people they had grown up with, in ways such as career advice, mental health support, motivation, and confidence. The weaker university ties developed by introductory students still yielded important supports in the form of instrumental actions. They described how they relied on professors, TAs, and classmates for specific help on projects and homework, among other instrumental supports. During the pandemic introductory students did not have opportunities to continue to develop these weak ties with professors, TAs, and classmates such that they would become strong ties because they no longer had face-to-face interactions with them. Because of this, introductory students continued to rely on their lifelong relationships. Few reported new friendships with peers from their university.

4.2 Summary of Advanced Student Results: Quantitative and Qualitative

Before the pandemic, students in the advanced course had well-developed social networks with their peers and professors that had developed over the course of the several years they had spent at the university. The strong ties with university alters are reflected in the quantitative data (Fig. 1) where 46% of advanced students named professors as significant alters and 20% named peers as significant alters. Unlike the introductory students, the advanced students named significant alters with a variety of relationship lengths corresponding to their time in college (Fig. 2), including relationships of a year (12%), two years 16%), three years (20%), and four years (17%). In the interviews, advanced students described how they relied on frequent interactions with university alters for both instrumental and expressive supports, such as developing career plans and working on projects. In interviews, participants also described how they relied on both in-class interactions and more casual interactions, such as meeting in the halls or working together during open lab hours, to build and maintain these networks and to utilize their networks for supports, such as comparing internships experiences and discussing changes in personal lives. Both the qualitative and the quantitative data revealed that advanced students also had strong networks with their families and friends (indicated in the quantitative data which showed 26% of identified alters were lifelong relationships). They maintained these networks remotely and through interactions such as weekly phone calls and summer trips. In the interviews, advanced students described how professors and classmates remained important to their success and persistence during the pandemic. They maintained relationships with classmates by meeting over video calls to work on projects, checking in with each other through group text chats, and purposely planning time to catch up with each other before and after project meetings. Nonetheless, they described how being cut off from the casual interactions they had relied on had hampered their wider social networks and weaker ties. This resulted in many students feeling that they had lost a community on which they had previously relied.

4.3 Alignment with Existing Social Capital Research in Engineering Education

Our findings support several key points from prior work in social capital theory in engineering education. We found that students at different points in their educational experiences relied on different types of alters for various types of support, a finding that aligns with Martin and colleague's work [16, 17]. Our work further demonstrates the important role of social capital from faculty and classmates in interactions inside and outside the classroom in student success, aligning with extant literature [16, 17, 21–23].

Similar to other recent research, our findings indicate that advanced students had well-developed social networks cultivated over the course of several years of their university education while the introductory students – much like first-year students in other studies – primarily still relied on alters from their lives prior to entering college [17, 24]. Like Puccia and colleagues [24], we found that as students live away from their parents, they rely more on university alters for instrumental supports, although they often continue to rely on their families for expressive supports [24]. Our findings also mirror another recent study of students' social capital during the COVID-19 pandemic that found that students with stronger, more developed social capital felt more supported and stayed more successful during the pandemic [25].

The differences we found with respect to strength-of-ties for the two groups of students are theoretically confirmed by Lin's [18] Network Theory of Social Capital. The advanced students in our study had previously developed strong ties with university alters over several years and through frequent, casual interactions that are char-

acteristic of strong ties. These are the ties through which expressive supports are exchanged. On the other hand, introductory students had not yet developed strong ties with university alters, because they did not have the "intensity, intimacy, [and] frequency of contacts" [18] that the advanced students experienced. Consequently, when the pandemic forced both groups of students to receive their courses online, the advanced students expressed a sense of loss of community (indicating strong ties) but the introductory students did not feel the same loss (indicating weak ties). While the introductory students did not have strong ties with university alters from which they could derive expressive support, they did rely on their weak ties with those at the university to provide valuable instrumental support [18].

4.4 Contributions to Understanding Impact of Pandemic on Engineering Education

Although college students have been cut off from their social networks for individual reasons in the past – including illness, death of family member, and financial struggles – the COVID-19 pandemic was the first system-wide event in recent history that has cut off all in-person social interactions. This represented an unprecedented threat to the social networks that had previously supported students' academic success and persistence. This study makes a unique contribution to the education literature in part because it was conducted at a time in history when students' academic social capital changed drastically in a very short period of time, giving us the opportunity to understand how this simultaneous systemwide isolation from their social networks affected a large group of engineering students. Our study gives insights into how students social networks change when they are cut off from face-to-face interactions.

We studied two groups of students at the same university during this unprecedented time period: introductory and advanced engineering and engineering technology students, collecting survey and interview data during the latter part of the Spring 2020 term. We investigated changes in the instrumental and expressive supports on which student had previously relied for persistence and success in engineering. The advanced students poignantly described an acute sense of loss for the close-knit university community with whom they had previously had frequent interactions and regularly garnered expressive and instrumental support. However, many had developed strategies to reconnect with their networks after an initial period of isolation. The introductory students described only interacting with alters with whom they previously had strong ties, including family and a few select peers. The weak social ties the introductory students had only begun to develop at the university did not develop into stronger ties and began to dissolve during the period of ERT.

Despite the challenges of maintaining social networks during the pandemic, our work provides rich examples of how students found ways to maintain their networks, such as setting up video calls outside of class hours and purposefully maintaining the casual interactions they had previously taken for granted. Students experienced a loss of motivation, difficulty with specific learning concepts, and generally frustration with their education when they were cut off from their networks. However, when they were able to connect with the important alters in their lives – even through small things such as talking to a friend over a balcony railing or a brief virtual office hour visit with a professor – they felt more supported in these areas.

The strategies students used to maintain their networks can help educators better understand how to facilitate support for individual students who may be cut off from their social networks and also give us insights about how to more intentionally facilitate robust student networks for everyone that could withstand another disruption [26, 27]. Our work supports that of other researchers [28] who suggest strong social capital was an important indicator of effective community responses to disasters in the past as well as the COVID-19 pandemic, models from which universities might benefit. The strategies students employed demonstrate not only how it may be possible to maintain a social network in constrained circumstances, but also how valuable students consider their social networks to be. This underscores the importance of helping students build and utilize their social capital.

5. Implications

Disruptions, whether pandemics, fires, extreme weather, or war, are by definition unplanned events. While no one can predict such disruptions, academic institutions and instructional teams can be better informed and ready for future disruptions. The implications of this study and the body of literature coming out related to education during COVID-19 can serve to prepare education systems to minimize the negative consequences to students' education in future disruptions. Our findings point to the critical role of campus alters and the need for institutions to scaffold students' development of the those in their networks from the moment engineering students begin their degree program. Our findings point to the need for students to be aware of the importance and robustness of their social networks.

We advocate for universities to transmit this message to students and encourage them to maintain their connections during periods of disruption, should they arise. This could be done by faculty, advisors, administrators, and student groups. To support peer-to-peer social capital during online learning, instructors could encourage students to get to know their teammates personally, establish virtual co-working times for teams, utilize a course-wide messaging tool (e.g., Slack, Discord, GroupMe), and organize breakout rooms during online classes to have a dedicated time for students to collaborate on projects. To establish and maintain instrumental and expressive social capital with students when teaching online, faculty could schedule synchronous class times to open a few minutes before and stay open a few minutes after class time and use the time to have conversations with students. To promote clear communication and manage expectations, faculty could inform students about mechanisms for getting questions answered (e.g., email, learning management system, messaging application) and when they can expect a reply. Since it can be more intimidating for a student to request a meeting than to come to scheduled office hours, faculty could host virtual office hours and encourage students to drop in to chat or to ask questions. During times of disruption, faculty can also proactively reach out to students rather than waiting for problems to arise.

6. Conclusion

Our work points to potential longer-term effects of the disruption of social networks caused by the pandemic, especially for the students whose first year (or more) at the university was interrupted. These longer-term effects may include lacking the skills or opportunities needed to develop strong social networks, students being isolated without the supports they need, and the negative effects the lack of a strong network could have on their education and career attainment. The rich connections advanced students described (even if they were disrupted) offered benefits that students a few years behind them may not be able to recover. Further study will reveal how the disruption in academic social networks caused by the pandemic will play out in these students' academic careers and lives.

References

1. B. Kovacs, N. Caplan, S. Grob and M. King, Social networks and loneliness during the COVID-19 pandemic, *Socius: Sociological Research for a Dynamic World*, **7**, 2021.
2. E. Aboagye, J. A. Yawson and K. N. Appiah, COVID-19 and E-Learning: The challenges of students in tertiary institutions, *Social Education Research*, **2**(1), pp. 109–115, 2020.
3. A. Bierman, L. Upenieks and S. Schieman, Socially distant? Social network confidants, loneliness, and health during the COVID-19 pandemic, *Social Currents*, **8**(4), pp. 299–313, 2021.
4. R. M. Díaz-Jiménez, F. Caravaca-Sánchez, M. C. Martín-Cano and Y. M. de la Fuente-Robles, Anxiety levels among social work students during the COVID-19 lockdown in Spain, *Social Work in Health Care*, **59**(9–10), pp. 681–693, 2020.
5. A. W. Irawan, Dwisona and M. Lestari, Psychological impacts of students on online learning during the pandemic COVID-19, *KONSELI : Journal Bimbingan dan Konseling (E-Journal)*, **7**(1), pp. 53–60, 2020.
6. E. Kohls, S. Baldofski, R. Moeller, S. L. Klemm and C. Rummel-Kluge, Mental Health, Social and Emotional Well-Being, and Perceived Burdens of University Students During COVID-19 Pandemic Lockdown in Germany, *Frontiers in Psychiatry*, **12**, Apr. 2021.
7. J. M. Vaterlaus, T. Shaffer and L. Pulsipher, College student interpersonal and institutional relationships during the COVID-19 pandemic: A qualitative exploratory study, *Social Science Journal*, 2021.
8. The Healthy Minds Network and American College Health Association, The impact of COVID-19 on college student well-being, pp. 1–11, 2020.
9. S. J. Hausfather, Vygotsky and schooling: Creating a social context for learning, *Action in Teacher Education*, **18**(2), pp. 1–10, 1996.
10. L. Vygotsky, *Mind and Society*, Harvard University Press, 1978.
11. L. Vygotsky, *Thought and Language*, Cambridge, MA: The MIT Press, 1986.
12. N. Cross and A. Clayburn Cross, Observations of teamwork and social processes in design, *Design Studies*, **16**(2), pp. 143–170, 1995.
13. A. S. Palincsar, Social constructivist perspectives on teaching and learning, *Annual Review of Psychology*, **49**, pp. 345–375, 1998.
14. J. N. Cummings, B. Butler and R. Kraut, *The quality of online social relationships*, 2002.
15. C.-H. Tu and M. Mcisaac, The relationship of social presence and interaction in online classes, *The American Journal of Distance Education*, **16**(3), pp. 131–150, 2002.
16. J. P. Martin, M. K. Miller and D. R. Simmons, Exploring the theoretical social capital 'deficit' of first generation college students: Implications for engineering education, *International Journal of Engineering Education*, **30**(4), pp. 822–836, 2014.
17. J. P. Martin, S. K. Stefl, L. W. Cain and A. L. Pfirman, Understanding first-generation undergraduate engineering students' entry and persistence through social capital theory, *International Journal of STEM Education*, **7**(1), Dec. 2020.
18. N. Lin, *Social capital: A theory of social structure and action*, Cambridge University Press, 2001.
19. J. W. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches*, 2nd ed. Thousand Oaks, CA: SAGE, 2003.
20. J. Walther, N. W. Sochacka and N. N. Kellam, Quality in interpretive engineering education research: Reflections on an example study, *Journal of Engineering Education*, **102**(4), pp. 626–659, Oct. 2013.
21. I. R. Beattie and M. Thiele, Connecting in class? College class size and inequality in academic social capital, *Journal of Higher Education*, **87**(3), pp. 332–362, May 2016.

22. S. A. Brown, D. Street and J. P. Martin, Engineering Student Social Capital in an Interactive Learning Environment Engineering Student Social Capital in an Interactive Learning Environment, *International Journal of Engineering Education*, **30**(4), pp. 813–821, 2014.
23. S. L. Dika, Relations with faculty as social capital for college students: Evidence from Puerto Rico, *Journal of College Student Development*, **53**(4), pp. 596–610, 2012.
24. E. Puccia, J. P. Martin, C. A. Smith, G. Kersaint, R. Campbell-Montalvo, H. Wao, R. Lee, J. Skvoretz and G. MacDonald, The influence of expressive and instrumental social capital from parents on women and underrepresented minority students' declaration and persistence in engineering majors, *International Journal of STEM Education*, **8**(1), 2021.
25. P. Giavrimis and S.-M. Nikolaou, Social capital during the COVID-19 pandemic, *European Journal of Education Studies*, **7**(8), pp. 1–16, 2020.
26. K. A. Douglas, A. C. Johnston, J. P. Martin, T. Short and R. A. Soto Perez, Instructors' Facilitation of Student Connections Support Students' Success During Times of Crisis, *Computer Applications in Engineering Education*, 2022.
27. A. C. Johnston, K. A. Douglas, J. P. Martin, T. Short and R. A. Soto-Pérez, (2022). Promoting Student Support in an Online Fundamental of Electronics Course, *IEEE Transactions on Education*, **65**(3), pp. 394–401, 2022.
28. N. Pitas and C. Ehmer, Social Capital in the Response to COVID-19, *American Journal of Health Promotion*, **34**(8), pp. 942–944, Nov. 2020.

Appendix

Students' self-reported demographic information

		Number of students	
		Intro students	**Advanced students**
Gender	Female	36	9
	Male	54	31
	Trans	0	1
Race/Ethnicity*	American Indian or Alaska Native	0	2
	Asian	38	11
	Black or African American	1	1
	Hispanic or Latino	8	4
	Native Hawaiian or other pacific islander	2	0
	Other	2	0
	White or Caucasian	52	31
Year	First year	90	0
	Second year	2	1
	Third year	0	15
	Fourth year	0	21
	Fifth	0	3
	Greater than fifth	0	1
First generation college		15	9
International student		24	5

* Some students listed more than one race/ethnicity.

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