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How engineering instructors supported students during emergency remote instruction: A case comparison

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Abstract

The rapid move to emergency remote teaching (ERT) during spring 2020 revealed many challenges for instructors, especially for the team and project-based courses that previously relied on informal, in-person interactions and laboratory equipment. The purpose of this case comparison study is to learn from this transition to identify ways that instructors can support the success of students in online, project-based courses during times of crisis. We use data from student surveys, student and instructor interviews, and course documents to examine ways that student–student and student–instructor relationships changed during the move to ERT and how instructor decisions affected these relationships. We frame our work with social capital theory and social constructivism, specifically the community of inquiry framework. We examine two case studies: a first-year engineering course and a junior-/senior-level engineering technology capstone course, both with large class sizes at a large research university. In both cases, students indicated that the shift to online learning decreased their access to relationships and supports from people who influenced their success and persistence. Although the instructors approached the transition differently, the data and analysis support recommendations for future moves to ERT in project-based design courses. Recommendations include: Establishing mechanisms for informal conversations between students and between students and instructors; establishing a weekly routine that includes some level of real-time, verbal communication; instructors being available for just-in-time feedback and questions as they arise; and establish a backup plan for ERT learning objectives, should the physical facilities no longer be accessible.

KEYWORDS

case study, community of inquiry, design-based learning, emergency remote teaching, engineering education, social capital

1 | INTRODUCTION

Although many universities have invested heavily in expanding their online course offerings in recent years, when administrators canceled residential courses in the Spring of 2020, universities and college campuses across the world were caught off guard. Instructors typically had one to two weeks to create emergency remote teaching (ERT) versions of their courses (see for example, Affouneh et al. [1]). For many instructors and administrators before 2020, the thought that universities could be forced to move to remote teaching without notice was unimaginable. At the time of this writing, vaccines have begun to be distributed in some parts of the world and the light at the end of the pandemic tunnel is coming into view. There are many lessons to be learned from this experience to enable instructors and university administrators to be better prepared for future crises.

The COVID-19 pandemic was not the first time in modern history that educational entities have had to quickly pivot to ERT in response to an emergency [31]. For example, researchers described how the #Fees-MustFall movement in South Africa led to the closure of three University of Pretoria campuses in 2016 as “the university switched overnight from predominantly face-to-face (F2F) to online teaching and learning (OL), just after the start of the fourth quarter” [25, p. 91]. Other examples have occurred when students and schools have been the targets of violence and to keep students safe, their courses were moved online [11]. The previous quick transitions to remote learning have not previously led to a curated list of best practices to make a crisis transition from in-person to remote learning less disruptive for students in undergraduate education. Thus, across the world, institutions of higher education have followed very different paths [10]. It is almost certain that pandemics, natural disasters, and other catastrophes will create similar demands in the future. It is important to analyze the successes and challenges instructors have faced in 2020 and how they have supported students in particular course contexts. Increased knowledge about effective ways to transition to OL can improve how instructors adapt their courses to online [30]. Likewise, understanding the contextual factors (such as the course topics, learning goals, and students’ academic level) determining success is essential to shaping ERT in the future.

The move to ERT posed challenges for all instructors [23,33]; however, instructors teaching courses with project-based components faced particular challenges. Green et al. [17] discuss the importance of ERT courses to be designed with students’ affective needs in mind. They suggest activities such as Virtual Happy Hour to

acquaint students and teaching team members with the tools used for the course. Project-based courses are far less amenable to ERT because of team-based assignments, projects, and experiments with physical components, oftentimes requiring special machinery or lab equipment. Further complicating matters is the relatively limited research on project-based learning in online courses [29]. Instructors teaching these courses had to very quickly figure out how to replace the physical aspects of their course and still provide students a meaningful learning opportunity. Design courses have two crucial goals we will examine here: for students to genuinely learn what they need for their academic and professional careers, and for students to feel supported and have access to resources to be successful.

Under ERT during Spring 2020, students’ relationships, including with peers, faculty, and advisors, were no longer based on frequent, in-person interactions. This is concerning given that positive social interactions are critical for success in education. Relationships provide emotional support and access to resources [21], and social interaction is foundational for deeper levels of learning [18]. Although there are many established ways to communicate online, such as through discussion boards, these strategies do not replicate the in-person, often unplanned, supportive interactions that students relied on before the pandemic [20,26,34].

Social relationships and networks are critical for navigating undergraduate education [6]. Effective social interactions can support students’ development of deeper levels of understanding and critical thinking [15,18]. Social relationships are especially essential in engineering design-based projects because the process relies on interactions between students to achieve key learning objectives in both content and professional skills, including design thinking, collaboration, and communication skills [13]. Although technology can enable thousands of learners to access the same course content, a high-quality learning experience includes a genuine community of inquiry and social supports that provides access to resources and emotional support. Instructors work to design how to facilitate those crucial social interactions during the course delivery. The presence of the instructor and other learners is crucial to undergraduate students’ success and arguably as important as the quality of the content delivered in the videos or through other online resources [9,28]. Erickson and Wattiaux [12] found that during ERT in Spring 2020 science courses, students perceived that social presence varied the most compared to teacher and cognitive presence and predicted students’ satisfaction and engagement, and Venton and Pompano [35] found significant differences in student engagement in ERT chemistry courses when

students had higher levels of peer-to-peer interaction. Thus, the abrupt shift to online teaching had the potential to drastically affect students' learning, persistence, and success, demanding serious consideration of how to support students' relationships and their interactions around content.

In this case comparison study, we examine how two engineering instructors made the sudden shift to online courses and the resulting effects on students' learning performance and relationships with classmates and instructors. Our research uses the theories of social capital [21] and social constructivism, specifically the community of inquiry framework [2], to explore the effects of engineering instructors' choices during the COVID-19 pandemic in the Spring 2020 academic term. Our purpose is to identify ways that instructors can support the success of engineering students in online project-based courses. To do this, we address the following research questions:

1. How did instructor decisions during ERT change the social presence, teacher presence, cognitive presence, and academic social capital in project-based engineering courses?
2. How did these changes differ in introductory and advanced level courses?

2 | THEORETICAL FRAMEWORKS

2.1 | Network theory of social capital

Social capital is "resources gained from relationships" [21] that help an individual achieve a goal. The network theory of social capital focuses on the people in individuals' social networks and what types of resources they provide. It identifies two types of social capital: *Expressive social capital* is related to "physical health, mental health, and life satisfaction" [21, p. 244], and includes general emotional encouragement, empathy, and caring. *Instrumental social capital* helps an individual achieve a goal by providing tangible resources or information [21]. Social relationships are characterized by the strength of the relationship's ties. *Strong ties* are characterized by frequent, intimate, and/or informal contact over sustained periods, such as those with family and close friends; strong ties are often sources of expressive social capital. *Weak ties* tend to be more formal, less frequent, and less intimate, based on sparse contact (including people the individual has met only once or rarely communicate with; [21].) Weak ties can serve as bridges to unique resources outside the individual's

regular social circles, but rarely provide significant expressive social capital [21,22]. Studies using the theory to examine students' selection of and persistence in engineering majors [3–5] have highlighted the importance of expressive social capital for persistence; hence, it is the focus of this study.

2.2 | Community of inquiry

Although social constructivism is a broad theoretical framework building from the theories of Bruner [7,8] and Vygotsky [36], the community of inquiry (COI) framework is an increasingly common application of social constructivism for evaluating the effectiveness of OL [14]. Social constructivism describes learning as a process where one is actively constructing knowledge by incorporating new information into their existing mental schemes; social activity and language are key tools for learning [37]. Higher levels of functioning and critical thinking are developed through purposeful social activity, such as collaborative groups. Another key element of the learning process is regular support and feedback from a more knowledgeable other [18]. The COI framework applies these crucial tenets directly to OL environments as a framework for meaningful learning experiences through attention to aspects of instructor presence, social presence, and cognitive presence [16]. COI suggests that increased levels of social, cognitive, and teaching presence can all positively influence learning.

The COI framework speaks to the delivery of a course and how an instructor or teaching team facilitates an OL community. Although the development of new educational technologies and course designs will continue, higher levels of understanding and critical thinking demand discourse with others, including both peers and instructors. Engineering learners are expected to apply disciplinary knowledge to solve open-ended problems that have no single solution. Courses designed around social presence, cognitive presence, and instructor presence can provide online learners with an effective OL experience.

A summary of the relationships between COI and social capital theory is presented in Figure 1.

3 | METHODOLOGY

3.1 | Case study methods and quality considerations

We used case study methodology [38] based on two purposefully chosen project-based undergraduate

Social Presence	Cognitive Presence	Teaching Presence
Definition		
Affective connection between members of an online learning group; the ability for group members to project themselves socially and emotionally, as “real” people (i.e., their full personality), through the medium of communication being used. ^a	Constructing meaning through sustained communication. Cognitive presence is “more easily sustained ...when a significant degree of social presence has been established.” ^a	How instructors design the educational experience to facilitate social and cognitive presence in order to meet desired learning outcomes. ^a
Link to social capital		
Higher degrees of social presence result in expressive social capital that demonstrates caring and influences how students feel supported by peers, instructors, and teaching assistants. Higher degrees of social presence result in instrumental social capital that promotes exchange of information. ^{c,d}	Higher degrees of cognitive presence encourage development of relationships that help students exchange information and connect ideas, etc. ^a	Higher degrees of teaching presence led to more social capital.
Link to strength of ties^{b,e}		
Social presence is associated with stronger ties characterized by more familiarity, less formality, and higher degrees of trust. ^d	Cognitive presence promotes stronger ties through frequent and regular communication.	Teaching presence facilitates development of stronger ties that help students meet educational outcomes in part because they feel more supported and have higher degrees of access to resources.

^aGarrison et al., 2000. ^bLin, 2001. ^cRapanta et al., 2020. ^dTu & McIsaac, 2002. ^eMarsden & Campbell, 1984.

FIGURE 1 Summary of the relationships between the network theory of social capital and the community of inquiry framework.

Note: ^aGarrison et al. [15]; ^bLin [21]; ^cRapanta et al. [26]; ^dTu and McIsaac [34]; and ^eMarsden and Campbell [22]

engineering courses at the same institution. Here, a case study refers to the “empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident” [38, p. 18]. Our choice of methodology enabled us to deeply examine the differing contextual factors and instructional decisions made by the instructors of the two courses.

Case studies are not intended to be representative of a sample, but rather to expand and generalize theories. To achieve the goal of expanding and generalizing theories, Yin [38] recommends collecting at least six sources of evidence and triangulating the findings. Quality considerations for a case study include construct validity, internal validity, external validity, and reliability. Yin [38] suggests tactics that researchers can use to address the quality criteria. We have followed those suggestions with a few modifications, as follows. We describe how we ensured the quality of each aspect below.

3.1.1 | Construct validity

We used a previously published survey on social capital theory [5], used multiple sources of evidence, and had research participants review drafts before submission.

3.1.2 | Internal validity

Three independent coders established acceptable levels of inter-rater reliability for interview analysis. After synthesizing findings, we searched for negative cases, such as examples that feel outside the coding framework, in the interviews and addressed rival explanations.

3.1.3 | External validity

We used established theoretical frameworks, as described in the theoretical framework section, and replication logic in different cases.

3.1.4 | Reliability

We developed and used a case study protocol. Data is organized and stored in a case study database.

According to Yin, the most important consideration in selecting a case to study is access to data [38]. This was particularly relevant to our work given the need to collect data quickly as the ERT caused by the pandemic unfolded between March 2020 and May 2020. To address this consideration, we focused on two cases at one institution where we had professional contacts teaching courses of interest. Our decision to select cases from the same institution also allowed us to better focus on the course-controlled and instructor-controlled factors related to how the online changes were implemented because we held constant potential mitigating or confounding factors such as institutional responses to COVID-19 (e.g., dates of campus shutdowns and grading policies such as Pass/No Pass options) that would otherwise be present.

The first case is a first-year engineering course with learning objectives focused on introductory computer programming, teamwork, and introductory engineering analysis. The second case is a junior-/senior-level engineering technology capstone design course. Both courses focused extensively on teamwork and project-based learning, and both had fairly similar designs before the pandemic. However, class sizes were different—the first-year course had 120 students per section and the capstone course included 170 total students divided into teams of four to nine students—and the instructors made different decisions about the transition online.

3.2 | Case description

Both cases were courses at a large, public, research university located in the midwestern United States. The university made the decision to switch to ERT halfway through the spring 2020 semester, immediately before a week-long spring break. Therefore, students and instructors had less than a week to convert to ERT. The college of engineering at the university is made up of 9% underrepresented minorities and 26% women. Demographic information for the students in each case is presented in the Supporting Information [Appendix](#).

3.2.1 | Case 1: Introductory level course

The introductory level course is the second in a series of two that all first-year engineering students at the focal institution typically take. The course outcomes include a

range of engineering fields. Throughout the semester, students work in teams of four. The instructional tasks are supported by a graduate teaching assistant (TA) and four upper-division undergraduate teaching assistants (UTAs). The course is usually delivered in a flipped classroom format: students watch videos that present the content on their own time. Then, during the class sessions, which last 2 h, students interact with their professor, TA, UTA, and teammates to apply the information covered in the videos to complex problems. For the first half of the term, students work to develop basic coding skills. Then, the students work with their team on a project where they solve a complex problem by developing a coding algorithm. Typically, each class is divided into two, 1 h blocks. The first hour was comprised of reviewing the material, instructor-led demonstrations, and general student questions. Then, in the second half of the session, the students had studio time, where they worked on assignments and projects with their team. The instructor and members of the teaching team would walk around to teams to check in on work being done and answer questions.

In the Spring 2020 term, the university moved to virtual instruction after spring break. At this point, the students had just started working on their projects. The professor had some decisions to make. She decided to make class meetings optional and to provide recorded lectures for those who could not attend synchronously, recognizing that some students had returned to other time zones. She also continued to meet with students synchronously through video conferencing. The structure of these meetings was similar to the in-person version in that the professor made announcements, demonstrated content solutions, instructed students in the first half, then placed students in breakout rooms through the video conference software with their teams to work on their projects. The instructor and members of the teaching team would check on the teams individually to answer questions. Another change consisted of using an online communication application that gave students direct access to the instructional team at any time. This allowed swifter responses than e-mail. The third decision was to keep students who were able to attend synchronously in their existing teams. There were no more scheduled exams in the course, as the students had moved into their team-based projects.

The professor described how she did her best to transition the in-person active learning when the university moved to OL by making videos of course content that simulated what normally happened in class:

And, the videos were such that I would do what we would have been done in class as

videos. And, we wanted to still replicate that active learning piece. This is what's really new, and I think somewhat innovative about how we did this. What I would do is I would get to a point in the video, and I would say, "Pause here. Now, you need to go to this activity." And, either they were doing that activity in teams, or they were doing it individually. Even when it was in teams, we allowed them to do it individually, because of time zones.... That wasn't philosophy. That was more practicality at this point. They went off, and they worked on this individual or team activity. And then, they turned it into [an online grading system]. They would come back, and then I would do some follow-up conversation about it

3.2.2 | Case 2: Capstone design

Professors Howard, Fine, and Wade (all pseudonyms), who teach Capstone Design, took a different approach to teaching both cohorts taking the course in the Spring 2020 term, one of which had taken the first semester of the course in the Fall term and the other of which had not. In this course, students work on interdisciplinary industry-sponsored projects with two to seven other students under an industrial mentor and an academic mentor, a member of the school's engineering technology faculty. The main course goals are to develop teamwork skills in an industrial environment and develop skills integrating previously developed knowledge for solving engineering-technology design problems. As Professor Fine explained, the main goal of the course is

to get the students to understand the value of working together as a team.... [F]undamentally there's not anything new technically.... [T]hey've had all the technical courses. But how do you actually integrate all that knowledge together and also how do you actually... depend upon someone else to actually get that material done? We're trying to make them, I would say, something similar to a T-shaped professional where they are very deep in one technical area but they develop over time enough competencies across different disciplines to know when other people they can help or when other people are delivering the stuff

Before the pandemic, all three professors met during class times with students, which occurred twice a week for 3 h each. During these sessions, students worked with their teams on their projects, as well as some lecture material. Students met with both project mentors at least once a week, usually by teleconference, although some submitted email updates for this purpose. In addition, each team turned in draft reports three times each semester that the professors assessed. The instructional team also used peer-to-peer feedback as a tool for assessing students' performance in the form of surveys that were given to team members to give feedback to their teammates and professors about their team members' performance. Before the pandemic started, during class meetings, the faculty walked around the room and discussed project progress, individual contributions, and project demonstrations. Additionally, students had access to academic spaces for meetings and working on their projects at all times of the day and night.

After the pandemic started, the instructors decided to schedule individual team meetings lasting 10–15 min each week. Some teams met more often if needed. Meetings with mentors were not changed, although the timing was more flexible. The professors decided not to introduce any additional technology to support communication, instead using video conferencing, file sharing, and learning management programs that were already familiar to students. The professors did not establish any additional structure for students to meet together. The final submission was a written report as the students could no longer build their physical project or present their work in person.

3.3 | Data sources

We collected data from six sources from each case: (1) interviews with instructors, (2) interviews with TAs, (3) interviews with UTAs, (4) open-ended survey responses, (5) undergraduate student support (USS) survey, and (6) course documents such as syllabi. The introductory course's archived communications were available to the research team. Table 1 summarizes the data sources for each case.

3.4 | Recruitment and participants

We recruited instructors through personal conversations with instructors who were teaching the courses of interest. We sent emails to the undergraduates enrolled in each course expressing our concern for their well-being and asking them to participate in the survey, with the

TABLE 1 Number of participants who completed each data source

Data source	Introductory course	Capstone design
Instructor interviews	<i>n</i> = 1	<i>n</i> = 3
TA interviews	<i>n</i> = 1	n/a
UTA interviews	<i>n</i> = 1	n/a
Student interviews	<i>n</i> = 11	<i>n</i> = 8
Student open-ended survey	<i>n</i> = 27	<i>n</i> = 32
Undergraduate student support survey	<i>n</i> = 21	<i>n</i> = 29
Course documents	Syllabus	Syllabus
	Schedule	Schedule

Abbreviations: n/a, not applicable; TA, teaching assistant; UTA, undergraduate teaching assistant.

potential for a voluntary follow-up interview. Student demographics and distance learning environments are presented in the Supporting Information [Appendix](#). We obtained approval through the university's Institutional Review Board before any contact with and data collection from students and obtained informed consent was obtained from all participants.

Students completed the initial survey during the final week of the term and we compensated them for both the survey and the interviews. We asked six open-ended survey questions designed to elicit responses about students' feelings and experiences during the sudden shift to online instruction. The USS survey consists of two portions, modeled after the sociological tools for measurement of social capital [4]: a name generator and a resource generator. Name generators are designed to provide details about who is in a participant's social network. It directs participants to generate a list of names relevant to a particular context and characterize each relationship by answering questions such as the frequency of contact and length of the relationship. In our study, the survey prompted participants to list the names of people they considered influential to (1) their overall persistence and success and (2) their persistence and success in the course of interest. As name generator results in bias toward strong ties, name generators are often used in combination with resource generators, which are focused on resources derived from the participant's relationships with individuals in their network. Resource generators present a variety of possible resources and ask participants to identify categories of people who provided those resources, thus uncovering weaker ties. Adapting a list we used in other work in engineering education [4], we named 16 resources, such as talking about

engineering career options, encouragement to stick with engineering as a major, helping with the content of engineering courses, recommending courses the student should take, and introducing the student to people in their professional network.

From among those students who indicated they were willing, we selected interview participants based on maximum variation in their open-ended survey responses and reported changes in resources. We used the data from the survey to tailor portions of our semistructured interview guides to each participant. The 45–60 min interviews took place during Summer 2020 over video conference. We recorded all interviews and transcribed them verbatim. Demographic information about students interviewed appears in the Supporting Information [Appendix](#).

Our student interview guide consisted of four sections. Sample questions for each section appear in the Supporting Information [Appendix](#). The questions in Section 1 were consistent across all participants. We designed these questions to elicit responses about the participant's experience moving to OL, especially in the course of interest, and their experiences as undergraduate engineering majors. In Section 2, we asked follow-up questions about the student's open-ended survey answers. Sections 3 and 4 were tailored to each participant based on their survey replies to the name generator and resource generator items on the survey. We asked participants about each of the people they listed in the name generator portion of the survey. We used the critical incident technique throughout the interview to prompt participants to recall specific incidences and examples related to the general experiences they were describing [39]. Our questions focused on their relationships with the people they named, how those relationships changed (or not) during the pandemic, and specific times they felt supported by each person they named. We used resource generator responses to focus interview questions around differences in university-affiliated alters who provided various resources before and during/after the pandemic. We ended the interview by asking if there was anything else the participant wanted to share about their pandemic experiences that would help us support other students' success.

We also interviewed members of the instructional team for each course, with each conversation lasting approximately 45–60 min. For the first-year course, this included the faculty instructor, the TA, and one UTA. We interviewed each of the three capstone design faculty. The interview guide for members of the instructional team was based on concepts from social learning theory. We asked faculty instructors and the TA/UTA similar questions that were appropriate to their role. Although we asked the faculty instructors to share some general information about the course, their philosophy of how students learn the content, and their learning goals,

we asked TAs about how and why they became part of the instructional team, their goals as TAs, and how they believe students learn in the course. We asked all instructional team members a series of questions asking them to describe aspects of the course before and after the move to OL. These questions focused on student–instructional team interactions, student–student interactions, and the instructional team members’ observations about how students worked in teams. We asked the instructional teams about the decisions they made as they moved to fully online instruction, what they believed went well, and about the feedback they received. We ended by asking about the emotional, mental, and physical toll of suddenly switching to online instruction.

3.5 | Analysis

We conducted the analysis in several phases. First, for the preliminary survey analysis, we quantified and compared the numbers and groups of people students identified in the survey. We made graphs to visually represent changes that students identified in their supports. To analyze the student

interviews, we compiled from the interviews all the instances that students described interactions with others related to the course. We kept notes about how they interacted (e.g., synchronous or asynchronous, tools they used), what they were interacting about (e.g., project, personal matter), and instructor decisions related to the interaction. We compiled all the interactions that were directly related to the course in a single document and used this to create a codebook through an iterative process: three authors made an initial codebook together, all authors discussed the codes, the three authors coded four interviews together to consensus, and we divided the coding for the remaining interviews. We then grouped codes into broader themes, which appear in Table 2. Using the coding framework and themes identified from the student interviews, we compiled and coded the TA, UTA, and instructor interviews.

3.6 | Limitations

This study was conceived, and data was collected in the short time period between the announcement of the university moving to ERT and the end of the semester, a space of a month and a half. Therefore, although the surveys and

TABLE 2 Coding framework

Theme	Code	Type of interaction	Description
Changes in social presence	Sense of normalcy	All	The student described interactions that felt like conversations before the pandemic
	Small talk	All	The student described interactions that included conversations about the world outside the project
	Getting along with teammates	Student to team	Students described changes in their relationships with their teammates
Changes in cognitive presence	Changes in expectation/deliverables	All	The student described changes in outcomes and deliverables
	TA/UTA level of information	Student to TA	Students described the accuracy of the information they got from TAs and UTA
	Making content interesting, applicable	Student to instructor	The student described actions the instructor took to make the course content relevant to student interest
	Accountability	All	Students described anything related to accountability in their interactions
Changes in teacher presence	Instructor availability	Student to instructor	The student described how quickly and thoroughly the instructor responded to email or other methods of inquiry
	Empathy of instructor	Student to instructor	The student described their perception that the instructor understood what they were going through
	Communication frequency	All	Students described changes in how often they communicated with anyone related to the course

Abbreviations: TA, teaching assistant; UTA, undergraduate teaching assistant.

interviews were based on prior research and theory, there was insufficient time to validate the survey. Additionally, although we reach out to all students in the course, only a portion of those students responded to the survey and we do not know the experiences of the students who did not respond to our survey. This study focused on two cases of different approaches to ERT. Although we worked to ensure trustworthiness, as described in our methods, these cases are not generalizable across all experiences but do give insights into how instructor decisions influenced students in these contexts. Additionally, all data was collected from the same university. This gave us the ability to limit institutional differences in expectations for ERT, however, it did limit the breadth of experiences. Lastly, our communications with participants took place during the spring of 2020, after the pandemic had started. Although we asked them to describe changes caused by the pandemic, we did not have the opportunity to interact with them beforehand because we did

not know it was coming. The changes described here are, therefore, based solely on participants' descriptions.

4 | FINDINGS

In both cases, students indicated that the shift to OL decreased their access to relationships and supports from people who influenced their success and persistence. As shown in Figure 2, introductory-level students identified parents, peers, and faculty members as providing the greatest number of types of support. The percentage of responses for all university-affiliated groups went down during the pandemic more than the percentages of family support, indicating that students were relying more on their families for support during the pandemic than they had before. This change was also apparent in Capstone Design, as evidenced in Figure 3. Additionally, in the introductory course, support

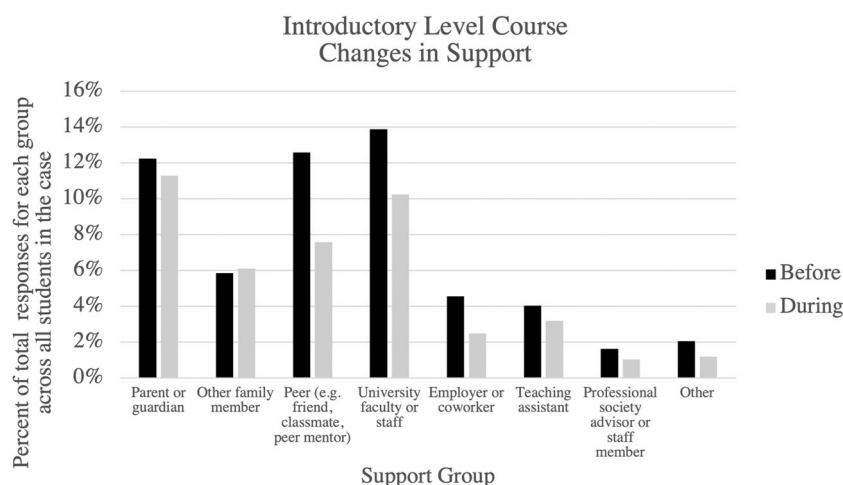


FIGURE 2 Introductory course changes in support

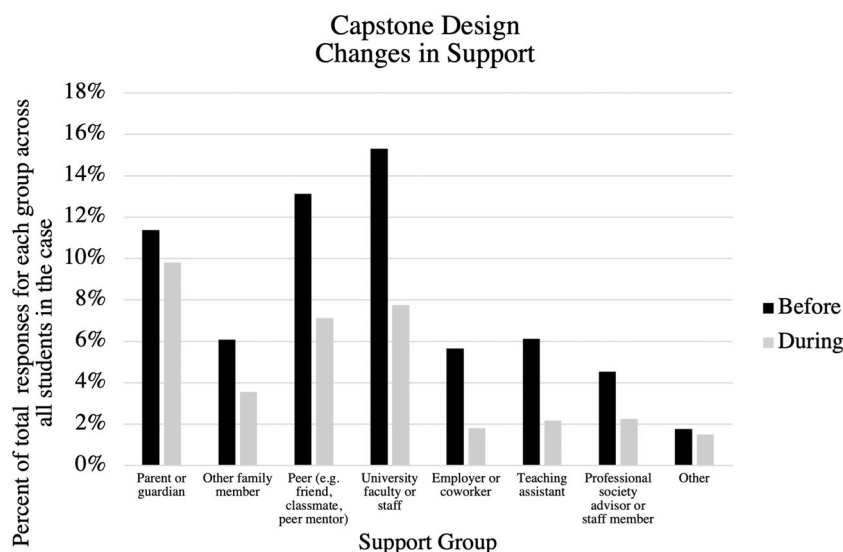


FIGURE 3 Capstone design changes in support

TABLE 3 Instructor decisions related to which coding themes they affected

Changes in social presence	Changes in teacher presence	Changes in cognitive presence
Instructor decisions in an introductory course		
• Maintained synchronous team working time • Kept the students in their teams and still required them to work together • Required students to make a plan to work together with their team	• Created an online communication channel/fast email response • Assignment reminders • Visited breakout rooms during class time • Kept (optionally) synchronous class meeting times	• Kept course deliverables the same • Made class meetings optional • Continued to include applications of content • Required students to make a plan to work together with their team
Instructor decisions in capstone design		
• Changed required meeting format from 6 h/week to 10 min/week • Did not establish a structure for students to meet together	• Limited meetings with the professor to 10 min/week • Response rate by email/unprompted check-ins • Continued to give helpful feedback on reports • Did not add new communication platforms	• Changed expectations for the project • Industry mentors remained readily available • Format of putting material online

from university faculty and staff went down less than in capstone design.

Through our analysis of the interview data, three themes emerged: changes in social presence, changes in teacher presence, and changes in cognitive presence. Each of these larger themes had several subthemes, as shown in Table 3. In this section, we will describe each of these themes, along with examples from the interviews.

4.1 | Theme 1: Changes in social presence

The transition to OL influenced social presence in courses in multiple ways, which this section describes from both the student perspective and the instructor perspective. Students emphasized changes in their interactions with their teammates. To a great extent, instructors could not control these changes, but some decisions that the instructors made positively or negatively affected social presence. These decisions and their effects on social presence are outlined in Table 3 and described using examples in this section.

4.1.1 | Introductory course

Students' comments suggest that the professor's decision to keep the students in their teams and to require them to work together was largely successful in maintaining informal peer-to-peer interaction. Allison recalled a meeting from before the pandemic and how she and her team

had stayed in a campus building into the wee hours of the night. She said that "as tiring as it was, it was really fun." Once interactions moved online, she said, "the same kind of thing happens during our calls; we would also stay up super late trying to figure out what to do and that happened a lot more [when the class was online] because it was a longer project." The similarity and sense of camaraderie provided a sense of normalcy.

Interviews also suggest that the decision to maintain synchronous working time at the regular class time was successful. This was especially salient for the teams that already got along well interpersonally before the pandemic. For example, Chloe said that her interactions with teammates were "honestly very similar." She explained that her team had "kind of the same relationship we had while at school" during remote learning: "We would often catch up about what was going on in our own hometowns and what they were doing...which was a really nice little bit of normal."

Frequent, informal interactions that the professor's decisions supported promoted stronger ties between teams. Paulo and Allison were on the same team. Allison talked about the expressive social capital their team built together:

Usually when we first logged on, we would spend like 10-20 min talking about what's going on with us. Like, how is the coronavirus in our areas. One of my group members [Paulo], was, I think he's from [another country] and he's stuck in the States, last time I talked to him. So, we were

talking to him about that, making sure he was OK. But then we moved on to working on... our projects and every once in a while, we'd get off topic and start talking about other stuff

In his interview, Paulo explained:

So my partners, like they were really supportive.... I was feeling very down because like I got the news that I was not going to be able to go back home, like right in the middle of our final project and I was feeling so bad. And I, sometimes I wasn't able to attend the meeting when they were like, "It's OK!" Like, "We couldn't imagine what you're going through."... Yeah, they helped me a lot

It was clear this expressive support had been vital to both Paulo and Allison, and notably, Allison felt good about the support her team had been able to provide to Paulo. On the other hand, some students described having somewhat weak ties with their teammates before the pandemic, and these ties further weakened with the move to online learning. These students felt that certain aspects of in-person interactions were not replicated online and felt a decrease in social presence. For example, Jacob explained:

[Before the pandemic] your group was more than just like, your people you worked with on assignments and that you'd like see each other on campus, which helps build the friendships, which makes your group work more comfortable, I guess. But then, after the pandemic happened and with classes going online, 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 a group that made group work kind of uncomfortable at times because we weren't really friends with each other

The loss of frequent and casual interactions with teammates made it difficult to build expressive social capital, although the team still offered instrumental social capital. The transition to online format negatively affected students' social presence with TAs and the UTA. Whereas these figures had offered instrumental social capital that went beyond the introductory course before the pandemic, as Ben described online teaching changed that, saying that

The transition to online format negatively affected students' social presence with TAs and the UTA. Whereas these figures had offered instrumental social capital that went beyond the introductory course before the pandemic, as Ben described online teaching changed that, saying that "before the pandemic the UTA would hang out [in the classroom] looking for people who had questions about MATLAB [programming language] 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 stuff like [names of specific engineering majors], and stuff like that

In this example, the student talked about casual interactions he had with the UTA in person that were not replicated online.

The results in this theme demonstrate the importance students placed on developing strong ties and expressive relationships with their teammates and instructors. Results from the survey also highlighted the importance of peer relationships in the classroom for the students and that they had less support from instructors than they might otherwise. For example, as shown in the data presented in Table 4 that is from the name generator portion of the survey, peers, both those associated with their college and those outside of it, as well as family members were influential to their success and persistence in the course and their major. The importance of relatively new relationships with alters associated with the university suggests it is important that the instructor made decisions that enabled the students to continue to develop and maintain their new relationships.

4.1.2 | Capstone design

Many of the capstone students described how they already had strong relationships with their teammates, characterized by frequent and informal interactions, before the pandemic. For example, Sophia said:

Before the pandemic... [my teammates] were great the whole time. They were just like a super capable team of people and I loved working with them, and they were also pretty friendly. I remember seeing them outside of capstone in a few places and just, I would stop and talk to them, like, you know, we were friendly and that was nice to have.... We would talk about personal things.... I

TABLE 4 Information about student relationships for the introductory course taken from the name generator portion of the survey

	Overall success/ persistence in engineering (% of responses)	Success/persistence in the course (% of responses)
Group		
Peer (friend, roommate, classmate, and teammate)	32	66
Professor	17	18
Family member	34	12
High school teacher	6	0
Other	11	4
Affiliated with the university, affiliated with a course		
Yes	50	70
No	50	30
Length of relationship		
1 year or less	43	86
2–5 years	7	0
More than 5 years	6	1
Lifelong	44	11

learned a lot about everyone's like classes and what they were going to do and boy-friends, girlfriends, stuff like that

Sophia described strong ties from before the pandemic that she was able to maintain or strengthen after the move to online, contributing to a strong sense of social presence. In general, if students had developed these ties before the pandemic, they were able to maintain or strengthen them after the move to online. In general, as shown in Tables 4 and 5, the students in capstone design had stronger ties with their classmates before the pandemic and were therefore better able to maintain these ties after the shift to online. This was influenced in part by the structure that the professor set up to meet during the pandemic, which was much less structured than the first-year course team interactions. The instructors rightly perceived that many students in their class had these close relationships. As Professor Fine said,

“They all knew each other so well.... [The transition to online] was very, very fluid [meaning smooth]. My biggest concern with doing everything online [in the future] is not having that stage where they actually know each other and enforce that responsibility on each other”

On the other hand, Capstone Design students described a learning curve in which they figured out how to best work together in the new environment.

For example, Chris said:

Basically, what ended up happening was our team only met when the professor scheduled a meeting and then even though some of us would try and get online like 5 or 10 min beforehand the professor would end up, would have to start the meeting for any of us to be online. Normally in class or 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, I guess, but as soon as, like if the meeting starts when the professor enters the room basically... you don't, you don't have that at all. So I guess... I was really good friends with a lot of people [before the pandemic]; 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, once the meeting started the professor was in the room. And then as soon as the meeting's over, the

TABLE 5 Information about student relationships in the capstone design course taken from the name generator portion of the survey

	Overall success/ persistence in engineering (% of responses)	Success/persistence in the course (% of responses)
Group		
Peer (friend, roommate, teammate, and classmate)	19	55
Professor	43	42
TA	2	0
Advisor	9	1
University staff	0	1
Industry mentor/employer	3	1
Therapist/success coach	2	0
Family member	21	0
High school teacher	1	0
Affiliated with the university, affiliated with a course		
Yes	71	77
No	29	23
Length of relationship		
1 year or less	13	83
2–5 years	50	12
More than 5 years	4	3
Lifelong	32	3

Abbreviation: TA, teaching assistant.

professor leaves and everyone's done and we already got what I guess we needed to talk about done at that point. So that was a little bit more of a downside. I think that was probably, in group-related activities, that's probably the biggest downside was that we couldn't have or we didn't have a small talk before like just to see, like catch up and see what's going on in everyone's lives before the professor entered the room

This example demonstrates that, from the students' perspective, the minimum expectations from the professor did not facilitate small talk conversations with teammates. It was more difficult to initiate conversations about topics unrelated to the project than when the students had been meeting in person several days a week before the pandemic.

However, just as the professor predicted, the students were able to establish ways to maintain their ties. Chris did note:

One thing I found that very helpful was just creating a secondary call or conference after the one with the professor, because sometimes that doesn't last as long and sometimes you still have a few more things that you want to say or discuss, but it's not really for the professor or he's not really required to, you know, it's just some like low-level stuff, or it could be stuff not related to the class at all

Chris's team found a strategy to continue to interact about the things unrelated to the course that helped maintain their ties with each other and their social support in the course.

Other students did not have as much success in self-regulating their continued social presence. For example, Sophia said:

After the pandemic, I never got to see [my teammates] in person again. So it was, I felt

like I have lost a little bit of my community, I guess, like not seeing them as much, I felt a loss from that. But, we still talked through [group messaging application] but there wasn't a whole lot to talk about. We just needed to finish up a few things. So mostly everyone did their work and then communicated that they had done their work and that was about the extent of it.

Sophia felt she had lost the community in spite of online meetings. The in-person environment provides social interaction online meetings did not.

Capstone design students identified several groups of people as influential to both their overall success and their success in the course. As shown in Table 5, data taken from the name generator portion of the survey, they most often identified professors as influential to their success and persistence in their major and largely identified both peers and professors as influential to their success and persistence in the capstone course specifically. The vast majority of the people they identified were affiliated with the university. Together, these results indicate that these older students rely more on university-affiliated relationships than the students in the introductory course. Additionally, the lengths of many of the students' relationships with others at the university have spanned 2–5 years, although they still rely heavily on newer relationships (less than 1 year) for support in the capstone course.

4.2 | Theme 2: Changes in teaching presence

This section describes some of the changes the transition to OL created in teacher presence from the perspectives of both the students and the instructors in both cases. Teaching presence changed because the teachers were no longer physically present with their students. However, the professors made decisions that affected how students experienced teacher presence while online. These decisions are outlined in Table 3 and described within examples in this section.

4.2.1 | Introductory level course

During the pandemic, Professor Smith made herself available in many different ways, including during class time through video conferencing and through the online communication channel outside of class time. Students such as Ben expressed appreciation for this:

Before the final, or... during the final or any exams, [Professor Smith] was like, "Look guys, I'm going to be on [the online communication channel] 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 get stuck on something and then have to wait like 20 min for [a] response." She was like, she was really on it. So that was really cool

In addition to this support, some students even suggested that they had more interaction with the professor after the pandemic started than before. When asked how her relationship with her instructor changed when the pandemic lockdown began, Allison said:

I probably talked to her more through [the online communication channel] and through [video conferencing] than I have talked to her in person, so I don't think it changed that much. She was actually kind of more available to us during the pandemic because she was on [the online communication channel]

This finding clearly suggests that the online communication channel was highly effective in making the professor available. Some students reported feeling similarly high teacher presence during the online video calls. For example, Chloe said:

In person during class, she would go around to different groups that they need help and stuff like that. And it often felt like there was just a lot going on. It's a big class, bigger than any other in-person kind of class that I had experienced before. And it felt a little rushed. [I] felt like I really had to like get to the point, and like, move on. But with even with the [video conferencing] calls it was a little more relaxed, because we were the only people in that little bubble in that little breakout room and it felt like she was like, she could see our screen, very invested in like figuring out the problem with us, her as well as any of the TAs that would join and help us. So, to me it was a little bit more comfortable in that sense. But also, she was definitely offering the same help she would have in person, which was really nice

However, not all students felt as supported during online learning. By contrast, Paulo said that before the pandemic he felt that interactions were “more personal” and he missed the ease of in-person discussion:

[L]et's say I didn't understand [the instructors'] response [to a question]. I would ask follow-up questions and I'll be like, “What do you mean by that?” or “Could you like elaborate a little bit more because I didn't understand it?” So after the pandemic, it was way harder, like even though it was from [the online communication platform] where, let's say, she could answer faster, it was still not the same. I still have to wait for her to respond and sometimes she took more than an hour, sometimes even a day. So it was not the same, like when she came back with the answer. So I think [the online communication tool] was probably—sometimes it was useless because I already have found by myself and I guess with my friends or my classmates.

Before the pandemic, Paulo felt he could get more thorough answers to his questions and ask follow-up questions. During the pandemic, even though the instructor worked hard to be available to the students and had fast response times for the communication method, some students did not feel as supported.

There was broader agreement that after the transition online interaction with the TAs and UTA decreased. Ben said that casual interactions had really decreased. While both the professor and TAs seemed available, some students felt less comfortable reaching out. Ben said: “I don't think I interacted with a single TA during the pandemic like because I didn't really ask questions. I was just kind of like picking their brain, I guess, and I'm not going to do that on [the online communication channel] because they have other stuff to do so.” Students had to take more initiative to ask questions and be more self-aware about how instructors could help them.

4.2.2 | Capstone design

Professor Howard described the process she used to determine that there would be far less frequent communication after the move to OL:

Well, the one thing we figured out really quick is, we can't do a regular old lecture... where you'd have 170 kids on the deal. So we

experimented with that over the spring break. We realized that wasn't going to work, so we quickly had to say we're going to schedule individual team meetings. So, the other thing we did was try to schedule a lot of these team meetings during the times [students] already have scheduled for classes and labs and with three of us doing that we just divided the groups up, relatively equally among us, and then we would rotate through to where I didn't always do the same ones.... It actually worked pretty well, especially early on... Probably about week three... we kind of realized... we didn't have to do as many of the meetings now, so we cut it back to once a week and that actually worked out pretty well. We could see that in the student evaluations... they really appreciated that because, I mean, they appreciated the fact that we were doing what we did but they appreciated the fact that we realized that yeah, after about three or four weeks [we needed to adjust]....

Here, the instructor described the efforts he and his colleagues went through to most effectively meet with teams of students and maintain teaching presence in the course.

4.3 | Theme 3: Changes in cognitive presence

In the introductory course, the students' projects were primarily online even before the pandemic. Therefore, the instructor was able to maintain similar learning goals as before the pandemic. However, in the capstone course, the learning goals before the pandemic focused significantly on building a final, physical prototype. Without the ability to go into their labs to do this, the instructors had to make decisions to change the learning goals of the course. These two different situations resulted in different effects on the changes in cognitive presence. Instructor decisions that affected cognitive presence are outlined in Table 3 and described within examples in this section.

4.3.1 | Introductory level course

In the introductory course, the learning goals and cognitive expectations remained almost the same. Allison's comment that Professor Smith's comparison of “coding

with loops” to the video game Pac-Man “stuck in [her] head” and that this helped her “visualize what [she] was doing” suggests that the course was succeeding. Similarly, Matthew said that Professor Smith had presented

slides about how, what we were doing can translate into other engineering major[s] or other engineering professions, and I thought that was pretty cool to see how, even though it felt like, “Oh, we’re doing this and nobody ever does this [in real life]”... I didn’t understand some of [the examples], you know, because it was like, “Whoa, I don’t know what that means.”... We’re doing, we’re doing some sort of like regression plotting and stuff... It seems like, “Why would people use this?” But, and then she showed those slides. And I was like, “Wow. People actually really do [use these concepts in real life]”

These two quotes reflect the success with some of the major objectives of the introductory course. Another significant learning objective in the course was for students to learn how to work with teams to solve engineering analysis problems. To support this, Professor Smith required them to make a plan to work together during online learning. Ben described how this worked for his team:

One thing that I did like about [the introductory course] was they kind of like required us to work [how we would work together] out. So, in my computer science course, they’re just like, “OK, you have the same lab partners, just figure it out. Ready, go.” And then [in the introductory course], they made us submit a document that told them how we were going to meet and all that stuff so that they were kind of like holding us accountable

According to Ben’s description the introductory course requirement really helped his team stay on target, and other students mentioned similar impacts.

4.3.2 | Capstone design

Before the pandemic, the capstone course relied heavily on the student’s actual building and testing of their design. Isabel explained the impact of changing expectations because of this:

[The expectations for the project were] constantly changing. We never had a strict “What do you want” [conversation with the instructors], because we didn’t know how bad the pandemic was. Our professor wanted a PowerPoint presentation, wanted to do a virtual fair, it was just kind of constantly changing. You didn’t know what the hell he wanted until he just settled on just write a report, put all the pictures, put all the CAD files, just do that. And I think it was because [at our school] all the labs realized at that point, it’s useless to do physical work. It’s useless to create that work because they can’t see it, they can’t help you out with it. That real-life learning you want and want to show, you can’t do that. So they just said, just give me a summary. That’s the easiest thing they could do.

Professor Howard described the changes from his point of view:

We had an indication that this [pandemic] may happen so we had it where everything had to be working by the end of week nine [before spring break]. Now that happens, and that’s normal, for the most part, but we really pushed to make sure it was done before they left for spring break. So we do the bench lab demos... walk around and see it, so all the teams had their functionality done. Now, what we ended up missing was, OK, “Now, I may have all this stuff spread out on a lab bench, I haven’t integrated it into a nice, clean, fancy, nice package with all the nice bows and ribbons on it to where I could give to the client.” So we pushed everybody to get that done. We did that...so we could make sure we could work at making the best report possible over the last five or six weeks and finish up any kind of loose ends

According to Professor Howard, even though the students were unable to build and test their projects, they produced high-quality work. Therefore, although the nature of the cognitive presence changed, the instructors maintained high-level expectations and cognitive presence by still requiring the students to complete high-quality work and demonstrate their knowledge of design and project management.

It was difficult for some students to work with their team because of the shift to online learning and their

return to places in varying time zones. The instructor's lower involvement made it more difficult for the students to be accountable for their work. Professor Howard explained that before the pandemic:

When we see them not participating [during in-person classes] we're on them like a duck on a junebug saying, "Well, you didn't show up, what's going on?" We chase them down in class. We chase them down outside of class and then quickly find out that through conversations a lot of the students may have a confidence issue and we need to work through that

As well, giving the students more responsibility for managing their team's cognitive presence gave students opportunities to step up and take leadership roles within their teams and allowed teammates to find ways to hold each other accountable, instead of relying on the professor. Bopha said:

So, after the pandemic, [the professors] pretty much, like deadlines weren't necessarily a thing anymore... because it could be different for everyone. Like, some people they just don't have access to good internet or they don't even have [a] computer. They don't have the software, right, everyone can be in a different boat. So with the deadlines, like I said, being just end of the semester it's easy for people to just not do stuff. But like I said, [teammate name] did a good job being like "Hey everybody, don't forget this is due" you know, or "We have to do this."... [W]e use [file sharing platform] and it has like history of like who edited. So it's like, we know who's not doing the work. And so we, so literally, I even, just [would send a] reminder, like, hey, just so you know, remember that we can see who does what... like these are just little reminders. I think [they] definitely helped people to get their stuff done

In this example, Bopha described her team as being able to hold each other accountable and motivated to complete the work even without the professor doing so. The instructors' decision to change expectations for the deadlines may have contributed to these students taking more ownership of their own work and learning important skills about self-monitoring. Not all teams were as successful at holding each other accountable. Teams

that already had trouble working together before the pandemic struggled in particular. For example, Alexis said their

professor had come to our capstone quite often, multiple times a week, and would like give us guidance on what we should [be] trying to accomplish that week and different things that we could do to improve. So, having that in-person communication multiple times a week, I think, really forced my team to work together and to be better. And then when the pandemic hit, it went to the same—like one person didn't care. And then one kid, you know, like one kid was falling asleep [when we were trying to work together]

One decision the instructor made to support students' learning to hold each other accountable was to have students complete peer evaluations. Alexis praised this system, saying that because of them her teammates "knew that I wasn't going to put up with them not doing anything. So when I started to like push them like a little bit harder they would go on [the file sharing platform the team was using] and work on it." Professor Howard described this system:

So if the student's getting rated as ones and twos [from their peers, we want], them [to] turn around and be threes and fours. If you're a three that means you're meeting expectations. So that's what we're trying to get all the teams to be. We want a team of threes

Without the professors' direct involvement, however, this was harder to achieve.

In this section, we have described changes in students' experiences with respect to the components of the COI; that is, cognitive presence, social presence, and teaching presence. The students in each case had differences and similarities in their experiences. In the following section, we describe these cross-cases and relate the changes to our theoretical framework.

5 | CROSS CASE ANALYSIS AND DISCUSSION

In the results section, we described, from both the students' and instructors' points of view, how instructors' decisions played out in the courses for the individual cases. In this section, we will highlight the similarities and differences across the cases and relate those to our theoretical

framework. The differences concern the strength of ties across the cases and how people interacted, while similarities refer to how instructors supported cognitive presence.

5.1 | Differences in strength of ties

The pandemic created significant disruption in many aspects of students' lives. They described how the expressive and instrumental social capital associated with their institutional relationships helped them persist and succeed in their engineering courses. Across the two cases, there were differences in the students' initial strengths of ties before the pandemic, which affected the impact of OL. For example, in capstone design, the senior-level students had stronger initial ties with their campus support network. On average, these were the people in the survey whom they had known for longer periods of time than did the first-year students. The Capstone design students had also worked with their course teammates for longer before the pandemic than the first-year students. These stronger ties were important sources of social capital. The first-year students described weaker initial ties with their teammates and professors. Even though they continued to work with their teammates after the course moved online, they did not have strong institutional ties to rely on for expressive support. These students had not had the chance to benefit from months or years of opportunities to strengthen ties through spontaneous, informal F2F interactions. Therefore, after courses moved online, the students in capstone design were better able to stay in contact with their support system, better equipped to reach out when they needed help, and less in need of support from their professors to continue to work with their teammates than their first-year counterparts.

The strength of the students' ties with their teammates and instructor(s) affected the way they experienced social presence for the two courses. A key component of social presence is "the ability of participants in a COI to project themselves socially and emotionally, as 'real' people (i.e., their full personality)" [16, p. 94]. If students only interact with others with whom they have weaker ties, they are less likely to feel that their class community consists of "real people" and experience a strong social presence in the course [9].

5.2 | Differences in interactions

There were significant differences in how students and instructors interacted with each other after the shift to OL. This is not surprising given that the formats of communication shifted so drastically and quickly. In some ways, students felt that communication became easier. For

example, students described receiving more focused attention from their instructors when meeting with them online in a small group consisting of only their team, compared to more hurried interactions when the whole class met in person. Those students who felt that communication was easier also felt that teacher presence was stronger. This is in line with the findings of Erickson and Wattiaux [12] who found that in ERT animal science courses, students perceived high teaching presence, and Müller et al. [23] who found that teaching online removed some barriers for Student-teacher interactions. However, more often, students felt that communication with instructors became harder; for example, they discussed how it was more difficult to ask casual follow-up questions and that response times were slower than when the course met in person. When students were proactive in reaching out to professors and took advantage of the communication methods that the instructors had put into place, their teaching presence was still strong. However, if students did not take the initiative in communicating with their instructors, their teaching presence became weak. These findings and examples are in line with other research on distance learning [27]. The instructors made several decisions that helped support their teacher presence: the communication tool the introductory course professor used and weekly meetings with teams of students in the Capstone Design course. Our study demonstrates that such decisions can support connections between instructors and students. However, it also demonstrates that students have to take initiative to maintain communication with their instructors and take advantage of teacher presence opportunities.

5.3 | Social presence and teacher presence supported cognitive presence

Social presence and teacher presence both need to be designed to facilitate cognitive presence [15]. Students who perceive the higher social presence and teacher presence also perceive higher learning [24,32]. In light of this, the instructors made decisions designed to help the students more effectively reach the learning objectives of the course. These decisions and instructors' actions to facilitate the transition to OL were essential to improving social and teaching presence and therefore improving cognitive presence. The instructors of both courses should be commended for the thought, effort, and skill they applied to all the difficult decisions they had to make to ensure the best possible experience for their students. For example, although the instructors in each case made different decisions about how to support teamwork in their courses, in general, the decisions worked well for their student population. In the introductory course, Professor Smith scaffolded her students more by helping them to work

remotely with their teams. The capstone design students would not need accountability for making a plan to work together remotely, and normal class hours would not be as important. Likewise, the lighter support for the senior students gave them the opportunity to step up and learn more leadership and project management skills to take the initiative to figure out how to work together remotely. The differences between the two courses made each decision appropriate for supporting the cognitive presence of the students in that course.

Although the instructors were able to maintain high levels of social and teaching presence that supported cognitive presence, they also had to make decisions about the specific learning goals of the courses. For example, in the introductory course, the instructor made decisions to keep all of the learning goals the same after the transition online. The students were expected to continue to meet with their team and complete the same project they were set before the pandemic. They were able to do this with the resources they had. However, in Capstone Design, the students no longer had access to the physical equipment needed, so not all of the learning goals could remain the same. The primary learning objective originally was centered on students designing and building physical products to meet the needs of their clients. However, during the pandemic, students were not able to access the labs, tools, and supplies they needed to complete these. Therefore, the instructors made the decision to change the objectives to focus on writing a report that demonstrated the research and virtual work that the students were able to accomplish during the pandemic. Although this was a significant change, the instructors made decisions that facilitated the students getting the most out of the course and maintaining cognitive presence, even though they had to adapt the learning goals to meet the needs of their students in their current situation.

6 | CONCLUSION AND IMPLICATIONS

Pandemics, natural disasters, catastrophes, and crises are, by nature, unplanned events that can lead to serious disruption in education. We hope that the COVID-19 pandemic is indeed the only global disruption of our generation, yet future health and public safety concerns that affect higher education should be expected [19]. Therefore, it is imperative that instructors and administrators develop plans and design courses for quick transition [17]. During the COVID-19 pandemic, universities came to rely on educational computer systems through ERT. Our findings can inform efforts to plan for future

ERT in project team-based courses. In this comparative case study, we sought to understand how two different engineering instructors approached the move to ERT and the support students perceived to identify effective practices for design, project-based courses with significant project team interaction. Social interaction is a crucial aspect of undergraduate education in typical residential settings, including both that which is directly related to course content and that which is indirectly related, or purely social. Students with stronger initial ties from before ERT experienced more social capital than those who had only developed weak ties at their university. Instructors made a variety of decisions that affected students' experiences in different ways,

Our results imply strategies for instructors of team-based ERT teaching to utilize to support students' use of educational computer systems. We found that during the ERT, students in both courses communicated deep appreciation for having set times when they could discuss their projects verbally with their instructor as a team. Although the capstone students in our study managed their teams rather independently, in the introductory level courses, it was important for the instructor to ensure individual accountability in team projects. By providing opportunities for real-time conversation, instructors of project-based courses can promote a sense of normalcy, offer timely feedback, and promote accountability. In addition, our findings also suggest instructors of introductory-level courses should set up informal communication channels for students, as the students may not have shared personal contact information with each other before the ERT.

Based on our findings, we have the following recommendations for future moves to ERT in project-based, design courses:

1. Establish mechanisms for informal conversations between students and between students and instructors.
2. Establish a weekly routine that includes some level of real-time, verbal communication.
3. Instructors should be available for just-in-time feedback and questions as they arise.
4. Establish a backup plan for ERT learning objectives, should the physical facilities no longer be accessible.

During times of emergency, education can help provide a sense of normalcy to students [31]. Despite the uncertainty and upheaval that is inevitable during a pandemic, it is essential that instructors be able to quickly establish routine forms of communication with their students and facilitate formal and informal communication between students. Particularly during the chaotic periods, students need to feel connected to their

peers and instructors to know they are not going through the experience alone and can still be successful.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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PEER REVIEW

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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