

An Exploratory Analysis of the Impact of COVID-19 on Engineering Programs and Undergraduate Students*

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The rapid spread of COVID-19 across many parts of the United States (U.S.) in the early spring of 2020 required universities across the country to make dramatic changes, the most visible of which was closing their campuses to faculty and students and moving instruction online. Information about how universities, engineering programs, and engineering faculty in the U.S. responded to the changes remains limited. The purpose of this exploratory study was to identify the changes engineering faculty made to policies, practices, and courses and to begin to understand how the changes affected undergraduate engineering students. We utilized a cross-section research design in which we collected data from over 200 engineering faculty via an online survey. We analyzed the data descriptively and using basic inferential statistics. We found that all universities moved instruction online and most closed campuses. Multiple offered additional financial aid to students. Few engineering units took steps beyond what university leaders already had. Engineering faculty implemented a range of changes to their courses, including the elimination of assignments. We observed that most changes made assignments less collaborative and interactive. Finally, faculty reported hearing about students' multiple concerns, ranging from academic and technical challenges to challenges at home. We encourage universities to offer more support to faculty and students as online learning continues across the U.S. In particular, we recommend more outreach to students to build and maintain strong ties to the university and engineering units.

Keywords: undergraduate engineering education; COVID-19; student experience; instructional change

1. Introduction

The rapid spread of COVID-19 across many parts of the United States (U.S.) in the early spring of 2020 required universities across the country to make dramatic changes, the most visible of which was closing their campuses to faculty and students and moving instruction online [1]. Early evidence from other countries suggests that faculty expressed concerns about technical challenges, student cheating, the lack of face-to-face engagement with students [2, 3], and felt underprepared for online learning [4]. Evidence from the U.S. notes that students attending two-year institutions were more likely than students at four-year institutions to plan to enroll in fewer courses [5]. Many also are concerned that the interruption caused by COVID-19 could have lasting effects on undergraduate students [6], particularly low-income students and students of color [5, 6] and for STEM students generally [7]. For example, recent evidence from the U.S. suggests that non-STEM majors in a Chemistry course became less engaged in the course, particularly those activities dependent on a physical classroom [8].

While information about how colleges and universities in the U.S. are responding remains limited in general, we know even less about the impact on

engineering colleges, departments, and students across the U.S. Further, we do not know how those impacts may differ across institution types, notably those that serve predominantly white or Caucasian students (Predominantly White Institutions; PWIs) and those that serve large populations of racial and ethnic minorities (Minority-Serving Institutions; MSIs). The present study has two purposes. First, the study seeks to identify how the COVID-19 outbreak affected student-related practices and policies in engineering programs, departments, and colleges (hereafter, referred to as units) across the U.S. and undergraduate students themselves in the spring of 2020. Second, it seeks to describe ways in which those changes and challenges vary across institutions. The following research questions guided the study:

1. What changes did engineering faculty make to their courses and advising to adapt to campus closure?
 - (a) What differences emerged across institution types (PWI vs. HSI)?
2. According to engineering faculty, what challenges did their students experience in the wake of the outbreak and campus closures?
 - (a) What differences emerged across institution types (PWI vs. HSI)?

2. Literature Review

2.1 Undergraduate Engineering Studies in the U.S.

Engineering majors are increasingly sought after in the U.S., with almost 620,000 full-time students enrolled in 2017. This number is over 54% greater than it was in 2008 [9]. Almost 80% of undergraduate engineering students in the U.S. identify as male, and 62.5% identify as White. Just over 14% identify as Asian American, 11.1% as Latinx, and 4.1% as African American. Women of color, in particular, are underrepresented in engineering majors [10]. Engineering has a reputation for being a unique and challenging course of study. As with other STEM areas, some students also perceive engineering as exclusive and unsupportive of students, particularly historically underrepresented students [11]. Engineering is also unique in how students perceive it [12], both in terms of the engineering community's culture and identity. Researchers have characterized the engineering community as having a way of thinking that emphasizes applied and practical thinking and problem-solving, iterative design and strong communication, and seeking the "best" and not the "right" answers [13].

Engineering courses increasingly are hands-on. Though instructor-centered lectures are by no means a thing of the past, particularly in large courses, there has been a push to make engineering courses more student-centered and hands-on [14–21]. Alternatives to traditional, lecture-based courses include 'flipping' the classroom, where students watch the lecture on a video ahead of the class and instead spend class time completing hands-on work [22–25]; peer-led courses and study sections [27, 28]; collaborative and teamwork [29–33]; and laboratory and project-based learning [34–39]. Except for laboratory activities [40, 41], most hands-on learning activities depend on face-to-face learning. With few exceptions [42], it remains unclear how the move toward more engaging learning modalities will be affected by the move to online learning.

2.1.1 Underrepresented Students in Engineering Studies in the U.S.

As described above, women and people of color continue to be underrepresented in engineering majors [9]. Scholars point to several individual and institutional level factors that lead underrepresented students to leave engineering. Individual-level factors include a lack of academic preparation for the rigors of engineering [43–45], low self-efficacy [46], a lack of a sense of belonging in the engineering community [43, 45, 47, 48], and experi-

ences with racism [48–50] and sexism [51, 52]. Institutional factors include a lack of financial aid [53, 54], lack of representation of minorities in STEM in the media and among faculty [44], and admissions policies [44].

2.1.2 Minority-Serving Institutions and Engineering Studies

Minority-serving institutions (MSIs), either because of their founding (e.g., Historically Black Colleges and Universities, or HBCUs) or their enrollment, serve proportionally larger populations of underrepresented students than non-MSIs or predominantly White institutions (PWIs) [55]. There are at least five types of MSIs: HBCUs, Hispanic-Serving Institutions, Tribal Colleges and Universities, Alaska Native-Serving Institutions, and Asian American and Native American Pacific Islander-Serving Institutions [56]. As of 2016, over 700 MSIs served over five million students in the U.S. [57]. MSIs are more likely than PWIs to serve low-income, first-generation college students and students of color [58]. Indeed, some research has found that students of color, particularly African American students, prefer MSIs [59].

MSIs produce a disproportionately large number of STEM majors in the U.S. and are well-positioned to continue to do so [58, 60, 61]. According to a National Academies of Science, Engineering, and Medicine (2019) report, MSIs enroll more STEM majors than PWIs: In 2016, 43.7% of students at HBCUs, 48.4% of students at AANAPISIs, and 43.3% of students at HSIs were STEM majors, compared to 40% at PWIs. There are many reasons for this, and those reasons vary across institution type. Explanations include the more inclusive environments that MSIs provide due to their greater levels of student diversity [58, 62], a stronger sense of belonging [63], more minority faculty [58, 64, 65], and the use of culturally responsive teaching approaches [58].

2.2 Online Education in Higher Education

Universities have adopted different forms of online learning, though the integration of online modalities has been uneven across institutions. According to the National Center for Education Statistics, 35% of all undergraduate students were enrolled in at least one online class in 2018 [66]. Online teaching and learning can take many forms in higher education [67–68]. Courses can be delivered entirely online without face-to-face interaction, though only 11% of universities in the U.S. deliver all of their courses online [69]. Hybrid or blended learning occurs when part of the course content is delivered face-to-face, and part is delivered online [70]. The flipped classroom is where instructors

show instructional and lecture videos before class and utilizing class time for discussion or hands-on work [71].

2.2.1 Online Education in Engineering Studies

Online engineering education also has a growing presence across universities and presents both opportunities and challenges. Online engineering education has the potential to make engineering more accessible to more students, particularly to working professionals and non-traditional students [72]. Furthermore, it can help prepare engineering students for the rapid growth in virtual collaboration across engineering sectors and companies [73]. Furthermore, as technologies and software programs have improved, it has been possible to replicate some (though not all) laboratory learning, an essential component of engineering education [74], through online simulations and games [40, 72, 75–78].

The challenges to online engineering education are similar to other areas of education. For example, students must be self-motivated and comfortable working online [79]. A recent synthesis of research on engineering education in flipped classrooms highlighted both the challenges and benefits of incorporating an online component into engineering courses [80]. On the one hand, preparing for online learning is time-consuming for faculty. Students often report that online material is unengaging and that they had trouble regulating their learning. Finally, students may struggle to access online material because of connectivity and other technical issues. On the other hand, flipping the engineering classroom gives students more flexibility and autonomy vis-à-vis online work [80].

3. Methods

In this study, we adopted a nonexperimental, cross-sectional design to answer our research questions. We focus here on engineering faculty responses collected in the wake of the COVID-19 outbreak in the U.S. in the spring of 2020. In the remainder of this section, we describe our participants and how we collected and analyzed our data.

3.1 Participants

We recruited engineering faculty participants in several ways. First, we promoted the survey on social media, including Twitter (using the hashtag #engineering and tagging the American Society for Engineering Education) and LinkedIn. We contacted all of ASEE's division chairs and requested that they share the survey through their newsletters and listservs. We reached out to personal contacts, and we created a list of engineering faculty at

Minority-Serving Institutions (MSIs), and we emailed those faculty directly. In total, 206 engineering professors from across the U.S. completed the survey.

3.2 Data Collection

We collected data using an online survey. The survey had 36 items (available upon request). We first asked about the types of courses they taught in the spring of 2020 and then about the changes they made to those courses (nine items); these items were multiple choice. For example, we asked whether faculty eliminated assignments. We offered faculty an opportunity to elaborate on the changes using open-ended responses. We then asked about the strategies they employed to continue their courses in an online environment (nine items). For example, we asked whether faculty created and shared instructional videos with their students. We created these items based on a review of the best online education practices [81]. After that, we asked whether faculty had heard from their students about a series of concerns, ranging from logistical (internet connection) to person (caring for a parent) (20 items). We allowed faculty to elaborate or provide other examples in an open-ended response. We concluded the faculty survey with questions about their institution (e.g., whether the institution is large, medium, or small or an MSI) and themselves (e.g., race and ethnicity, gender identity, faculty rank). The institutional questions come from the Institutional Postsecondary Education Data System.

3.3 Data Analysis

Our data analyses were exploratory, consisting primarily of frequencies and Chi-square tests to test the hypothesis that the changes faculty made and the concerns they heard from students were related to institution type. For the open-ended responses, we read through all of the responses and created a set of themes. We used those themes (e.g., “changed group work into individual work”) to code the faculty's responses and then utilized frequencies to summarize the changes faculty made.

4. Results

4.1 Description of Faculty Participants

As depicted in Appendix A, faculty participants represented 38 states in the U.S., Puerto Rico, and two countries outside of the U.S., while unit leaders represented 13 states. Sixty-one percent of faculty teach at urban universities, 9% in suburban universities, 24% in towns, and 6% in rural universities. Three-quarters of faculty respondents teach at public universities. One-quarter of respondents

Table 1. Size of Universities Represented

Size of University	Percent of Faculty
Fewer than 2,000 undergraduate students	9.4
2,000–5,000 undergraduate students	15.8
5,000–10,000 undergraduate students	15.3
10,000–15,000 undergraduate students	11.3
15,000–20,000 undergraduate students	8.4
20,000–30,000 undergraduate students	14.3
30,000–40,000 undergraduate students	12.3
More than 40,000 undergraduate students	13.3

Table 2. Average Spring 2020 Course Sizes for Respondents

Average Course Size in Spring 2020	Percent of Faculty
Fewer than ten students	8.9
11–30 students	49.5
31–50 students	23.8
51–75 students	7.9
76–100 students	5.4
101–150 students	2.5
151–200 students	0.5
251–300 students	0.5
More than 300 students	1.0

Table 3. Positions and Ranks of Faculty Participants

Faculty Rank	Percent
Assistant Professor	18.9
Associate Professor	20.4
Full Professor	30.8
Instructional/Clinical Assistant Professor	8.0
Instructional/Clinical Associate Professor	3.5
Instructional/Clinical Full Professor	2.5
Lecturer/Adjunct Professor	15.9

teach at colleges that only have undergraduate engineering programs, 16% teach at universities with undergraduate and master's degree students, and just under 60% teach at universities with undergraduate, master's, and doctoral programs. Just over three percent teach at an HBCU, 18% teach at an HSI, 1.4% teach at a TCU, and 1% teach at an AANAPISI. The faculty teach at universities that range in size from small (< 2,000 students) to large (> 40,000 students), as depicted in Table 1.

Professors' average course sizes also ranged from very small (< 10 students) to very large (> 300 students), as Table 2 shows.

Finally, we describe the faculty themselves. Sixty-eight percent of respondents identify as male, 29% as female, and 0.5% as a different gender identity. Most respondents are White (78%), 4.3% identify as Black or African American, 5.3% as Latinx, 3.4% as Southeast Asian, 2.4% as South Asian, 2.4% as Middle Eastern, and 1% as Native Hawaiian and

Table 4. The Number of Courses Faculty Respondents Reported Teaching in Spring 2020

Number of Undergraduate Courses Taught	Percent
One course	25.9
Two courses	33.5
Three courses	21.8
Four courses	12.2
Five or more courses	6.6

Pacific Islander. In Table 3, we describe the positions and ranks of faculty participants.

4.2 Research Question 1: Changes Engineering Faculty Made to Courses and Advising

In this section, we report on the changes that faculty made in their courses in the spring of 2020, and we break down those changes according to institution type. Faculty reported teaching from one to five or more courses, as depicted in Table 4. In a regular semester, the overwhelming majority of our faculty respondents (79.7%) teach face-to-face, with only 2% teaching online only and 18.3% teaching in a hybrid format under normal circumstances.

Faculty reported making a range of changes to their courses in the spring of 2020. As depicted in Fig. 1, almost all reported moving their courses online (99%). Across the other changes we asked about, there was more variability. Somewhat fewer reported that they moved their office hours online (87.8%) and made changes to course assignments (83.2%). Just over half continued advising student research projects online (69.1%), eliminated course assignments (65.8%), or changed course assignments (54.1%). Just under half changed the grading policy for their courses (48%), held study sessions online (47.7%), or eliminated course requirements (42.3%).

We asked faculty to give us examples of the types of changes they made to their courses, and faculty reported a range of specific changes that they made to their courses. Table 5 describes the types of changes faculty made across their courses and the frequency of each type of change. Notably, some faculty reported they made one or no changes, while some faculty described making up to six changes to their courses. The most common types of changes made were moving instruction online and replacing in-class laboratory sessions with labs that students could complete at home with data or simulated labs. Many types of changes were aimed at creating flexibility for students, such as extending deadlines for assignments, making exams open-book and take-home, shortening assignments, and allowing presentations to be made via video. Other types of changes, however, were aimed at mitigating perceived opportunities for students to cheat. For example, one professor explained, "I had to change one of the

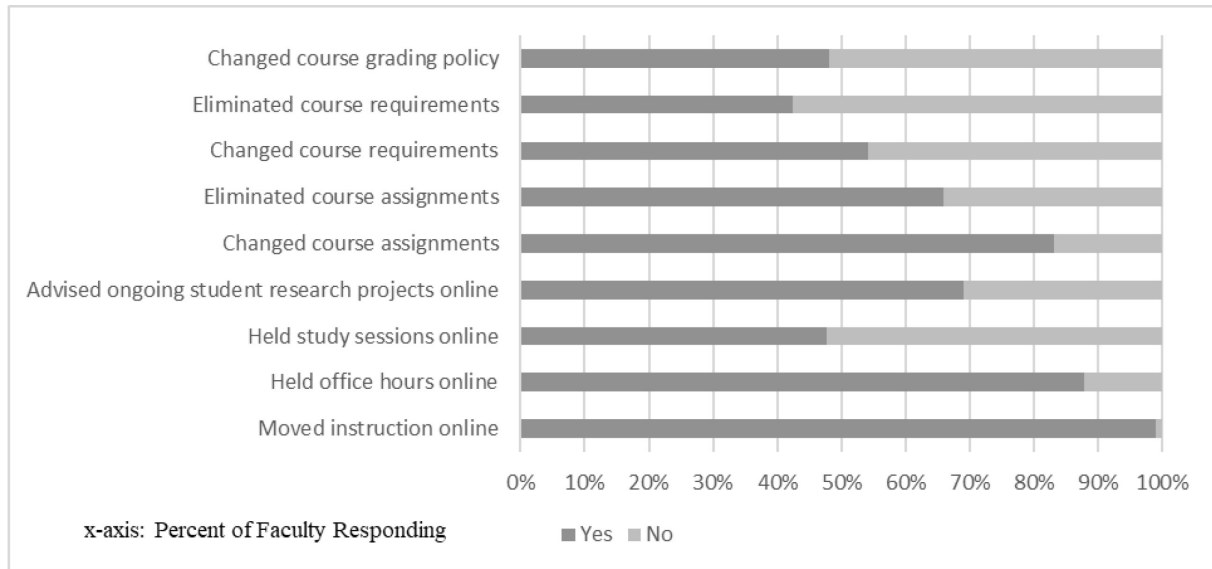


Fig. 1. Changes Made to Spring 2020 Courses.

Table 5. Practices Faculty Utilized

Remaining Classes	For all of my courses	For some of my courses	For none of my courses
Recorded videos or screencasts that were shared on LMS	57.0%	19.7%	23.3%
Assigned homework on LMS	74.7%	7.7%	17.5%
Assigned quizzes on LMS	51.6%	13.0%	35.4%
Assigned tests on LMS	51.1%	16.8%	32.1%
Created online workgroups for discussion	26.3%	25.3%	48.4%
Used online discussion board	33.9%	13.5%	52.6%
Asked students to create digital class presentations	31.4%	27.7%	40.8%
Did something else online	25.1%	7.6%	67.3%

midterms and the final to address issues of cheating when proper proctoring is not available.”

We followed up our questions about changes with a set of questions about what practices faculty implemented in all, most, or none of their courses. Table 5 summarizes their responses. We found that the most common practice (74.7%) was for faculty to assign homework online using the university’s learning management system (LMS). The least common practice was to create online workgroups to facilitate discussion (26.3%). The remaining changes echo what faculty described to us: Recording and sharing videos or screencasts (57%), assigned quizzes on the course LMS (51.6%), assigned tests on the course LMS (51.1%), used an online discussion board (33.9%), asked students to create digital presentations (31.4%).

Faculty reported using other strategies in all of their classes (25.1%) or some of their courses (7.6%). Those other strategies included holding online office hours (for some, those were held every day), employing simulation software, assigning videos on platforms such as YouTube, assigning

personal essays for students to express how they were coping with the pandemic, mailing lab kits to students so they could continue with hands-on labs and projects, using VPN connections to give students access to engineering software, holding virtual poster sessions, requiring students to give feedback on each other’s virtual presentations, offering tutoring and mentoring, and communicating with students via text in addition to standard channels of communication (i.e., email and messaging through the LMS).

4.2.1 Eliminated Assignments

We also asked faculty to give us examples of assignments they eliminated in the spring of 2020. In Fig. 2, we describe the types of assignments eliminated in response to campus closures and the move to distance learning. In some cases, faculty also offered explanations for their decisions to eliminate assignments. For example, some faculty described how it was no longer feasible to hold design and build competitions because of the specialized materials needed (e.g., a 450-pound beam). Others described

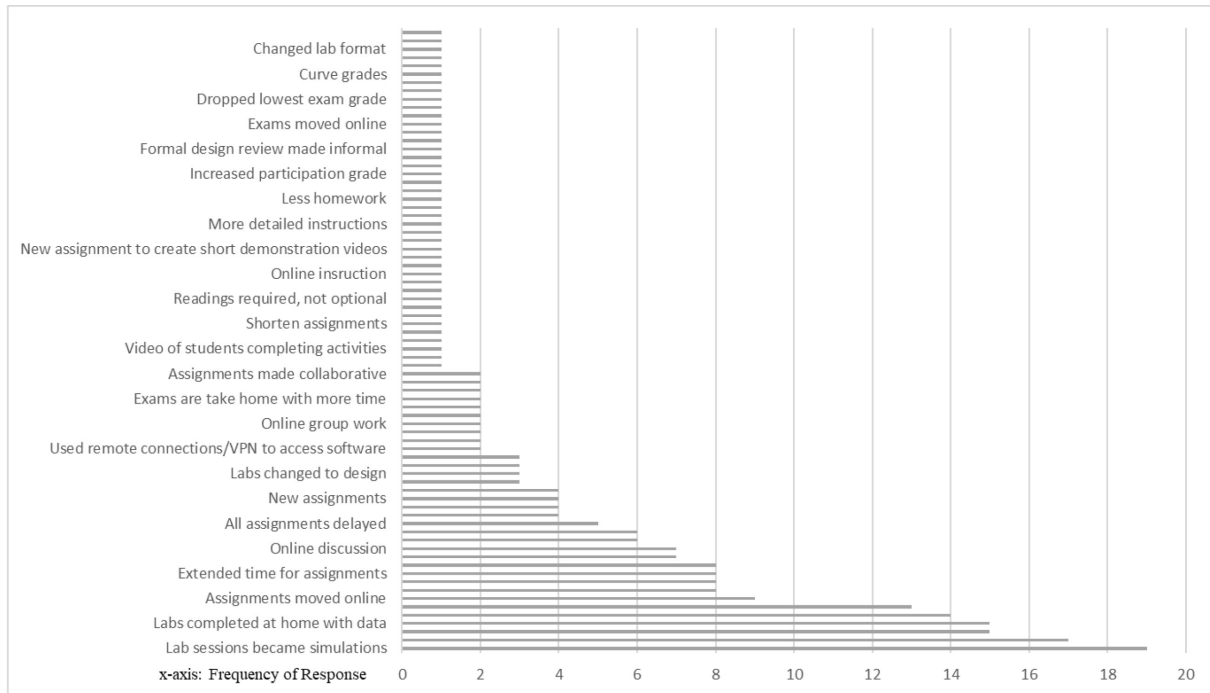


Fig. 2. Types of Changes Made to Courses.

the lack of access to software and hardware as a reason for eliminating assignments. At least one faculty member also recognized their limitations with young children at home. Finally, as with assignments that faculty changed, we also heard concerns about cheating: At least one faculty member cited cheating on an online exam as the

rationale for eliminating subsequent exams that would have been administered online.

4.2.2 Other Changes

Finally, we asked the faculty to describe what course requirements were changed and what additional changes they made (Fig. 3). Most faculty

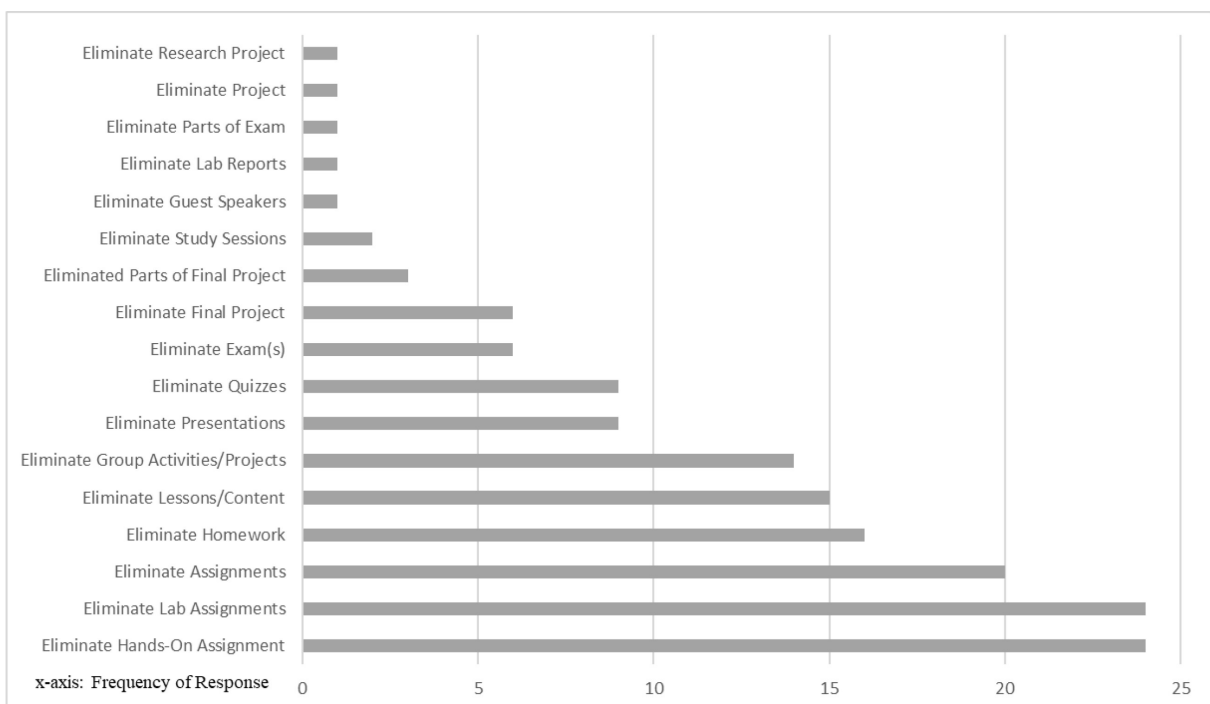


Fig. 3. Types of Assignments that Faculty Eliminated in Spring 2020.

responded that they did not change course requirements beyond the course changes they already had described. Several responded that they did not require attendance after the close of campus. Other changes included not holding problem sessions, grading on a curve, and grading more generously. One faculty member, concerned about the lack of face-to-face communication with their students, began sending daily emails to students (and some friends and family). They encouraged the students and discussed “normal happenings” as a way to maintain a connection

4.3 Research Question 1a: Differences Across Institution Type

We broke down professors’ responses according to the type of institution they work at (minority-serving institution) to identify any differences. To do this, we conducted a series of Chi-square tests. Here we report whether we observed any significant differences in the types of changes faculty made based on institution type (MSI vs. predominantly White institution; PWI). The chi-square test results did not reveal any statistically significant relationships between institution type or size and the types of changes faculty made to their courses.

4.4 Research Question 2: Student Challenges

In the final section of the survey, we asked faculty about their students’ challenges in spring 2020. It is important to remember that just as campuses closed down and many sent students home, unemployment began to spike across the U.S. as states closed down all but essential services. Unemployment increased most acutely for the Latinx and Black

communities [82]. As a result, universities and faculty worried about how to finish the semester and whether their students would finish the semester. Indeed, faculty heard from their students about a range of issues (Fig. 4). The vast majority of our faculty respondents heard from students about at least one personal concern from a student (61.3%), 61.5% heard about at least one financial concern from a student, and 92.4% of faculty respondents heard about at least one academic concern. When we disaggregate those concerns, the most common were academic concerns: Completing course assignments (72.7%), participating in online class sessions (60.7%), accessing the internet (67.8%), finding a place to study (51.4%), and accessing a computer (43.5%). A common personal concern for students was taking care of parents (41.9%). Faculty heard less from students about financial concerns such as about paying student loans after graduation (15%), paying for class materials (16.2%), paying for food (20%), finding a place to live (22.3%), or paying rent (23.3%). However, we speculate that students may only confide about such personal issues to professors with whom they have close relationships. As an example, one professor quipped in their open-ended response:

“How in the world would I know if my students have problems paying rent or taking care of siblings? Students don’t talk about such things with the professors, even when face-to-face classes are held. Maybe education majors or social science majors do that; engineering students are not concerned with looking for emotional support from their faculty/staff.”

Faculty reported additional challenges that they had heard about from their students. Those chal-

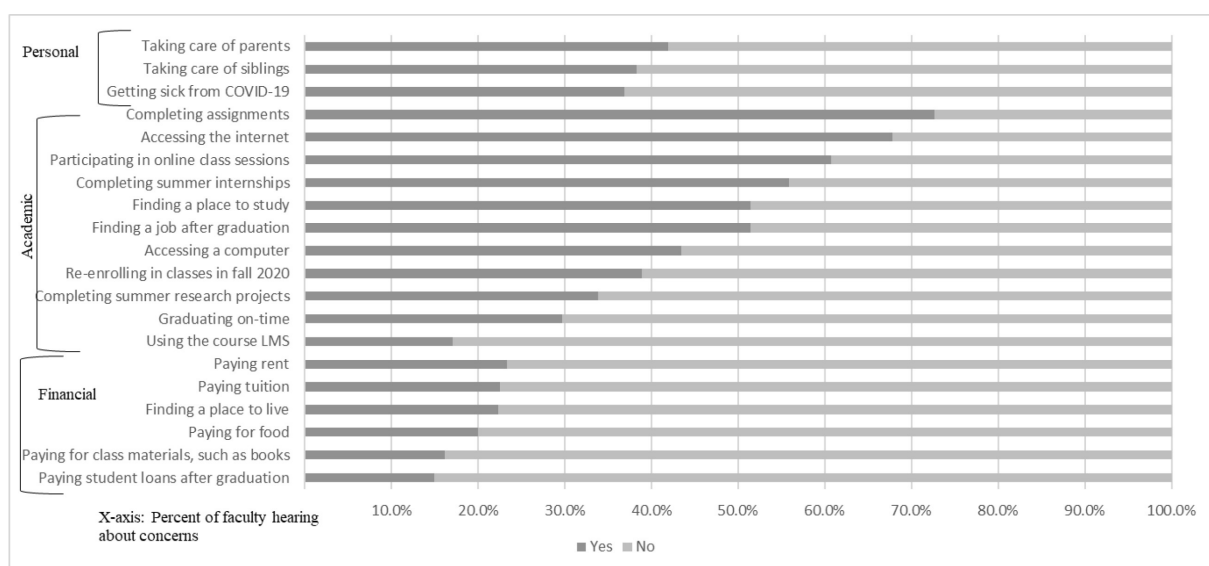


Fig. 4. Percent of Faculty Who Heard Different Types of Concerns from Students.

lenges included a lack of motivation, distractions at home including family obligations, unstable home situations, a sense of isolation, inaccessibility of courses or material for students with special learning needs, challenges carrying out group work, child care, loss of income, loss of financial aid, the withdrawal of internship and job offers and uncertainty about future job prospects, having COVID-19 symptoms but being unable to get tested, losing a family member to COVID-19, and depression and anxiety.

4.5 Research Question 2a: Differences Across Institution Types

We also wondered whether there might be differences across institution types. To test that hypothesis, we conducted a series of chi-square tests. Contrary to what we hypothesized, there was not a statistically significant relationship between whether the faculty respondent was at an MSI and whether they heard an academic, personal, or financial concern from a student generally. When we disaggregated the concerns, however, we observed three significant relationships: Professors at an MSI were more likely to have heard from students facing challenges using the course LMS ($\chi^2(df = 1, n = 181) = 6.00, p = 0.01$) with a small effect size ($\Phi = 0.18$), completing summer internships ($\chi^2(df = 1, n = 179) = 6.13, p = 0.01$) with a small effect size ($\Phi = 0.18$), and paying student loans after graduation ($\chi^2(df = 1, n = 180) = 3.81, p = 0.05$) with a small effect size ($\Phi = 0.15$). The remaining relationships were not statistically significant, indicating that professors at an MSI were no more likely to hear about student challenges than professors at PWIs.

5. Discussion

5.1 Implications for Research

Our study is one of the few to investigate the changes in engineering units and courses as the COVID-19 outbreak spread in the United States, and most universities closed their physical campuses and moved instruction online. In terms of how our findings contribute to our knowledge of engineering and online engineering education, we begin with a caveat: The emergency transition to online learning in the spring of 2020 is not comparable to traditional forms of online education, in which whole courses are designed from the beginning to be delivered online [68]. The concentration of changes points to a couple of possible explanations present in the online education literature: A lack of faculty preparation to adjust courses to online learning, lack of support and infrastructure for faculty to adjust courses,

and a lack of time for faculty to make the necessary changes [80, 83–87]. We also speculate that the emergency nature of the transition may have meant that faculty were overwhelmed with the additional workload and that, as with their students, they may have experienced physical and emotional fatigue due to the pandemic's uncertainties and the challenges of isolation. What is more, large proportions of faculty reported hearing from their students about their concerns, which we hypothesize may indicate that faculty spent more time than usual talking with individual students. Future research should investigate the faculty's experiences in greater detail, including their perceptions of online teaching and how the pandemic changed the nature of their work.

In reviewing the changes that faculty were most likely to make, we also conclude that the pandemic may have slowed the move toward student-centered learning. Among the course changes faculty were most likely to make were eliminating hands-on and group projects and replicating course lectures through video. Other examples included the cancellation of team-building activities and face-to-face labs. As research on student-centered learning notes, students benefit from having more agency in their learning and authentic learning experiences [14–21]. Future research on the impact of COVID-19 on teaching and learning in engineering should investigate which, if any, of the changes linger into future semesters, both as COVID-19 continues to limit face-to-face interaction and after the virus eventually subsides. Future research also should investigate the nature of instruction during spring 2020 and students' experiences with the rapid transition to online learning.

Another key finding is that, according to many faculty, some engineering students were struggling during the spring 2020 semester. Some faculty – and significantly more faculty at MSIs – reported hearing about challenges from their students, ranging from academic challenges (e.g., trouble concentrating, internet connectivity issues) to problems at home (e.g., students taking care of their kids, struggling with isolation, or living in an unsafe home). Some faculty, though, did not hear from students at all, and one bristled at the suggestion that students would confide in them. We suspect that the students whose professors did not report hearing about challenges were facing challenges but chose not to share. There are many reasons a student would not share such challenges with their professor, but one is that students may not trust, connect with, or may even feel rebuffed by their professors. Our finding that many faculty members had discussed students' personal challenges with

Table 6. Summary of Recommendations for Institutions, Instructors & Students

	Institution	Instructor	Student
Class organization	Instructional support to faculty	Smaller classes	
Engagement (in and out of class)		Additional office hours, Online mentoring hours	Sufficient/additional contact with faculty, Small group-peer learning
Assessment	Resources for designing online assessment		
Training	Instructional design support	Attend instructional design professional development	
Additional resources	Faculty incentives, Enhanced technical support for faculty and students	Online support communities for faculty	

their students provides some evidence that there may be some movement in the culture of engineering from one considered cold and closed [11, 50] to one that is more open and empathetic [88] as well as more welcoming to students of color and women [89], particularly at MSIs. We are unable to make a more conclusive statement because of the limitations of our sample. However, we urge researchers to speak with students directly to learn more about their experiences during the pandemic and the extent to which they felt supported by their professors. Fortunately, there are several studies underway in the U.S. to answer questions about students' experiences. Most evidence on students' struggles during the early months of the COVID-19 outbreak to date is anecdotal, from outside the U.S., or does not explicitly focus on engineering students. Given the challenging and historically exclusive nature of engineering studies, it is crucial to understand the extent to which COVID-19 interrupts or even derails students' engineering careers in the U.S., particularly for historically underrepresented students.

5.2 Limitations

Our study had two limitations. First, we collected data from faculty only once, at the end of the spring 2020 semester. Given the emergency nature of university shut-downs and the short time frame in which universities and faculty had to transition to

online learning, some of our findings may not generalize beyond spring 2020. Second, we did not survey students directly but rather surveyed their professors about them. For this reason, we may have underestimated the extent to which and the kinds of challenges students were struggling with in spring 2020.

5.3 Implications for Universities, Engineering Units, and Faculty

We offer several recommendations based on our findings (summary, Table 6). First, universities and engineering units need to support faculty in designing and delivering online learning, with special considerations made for different disciplines, such as engineering. Faculty, particularly those at universities that deliver instruction face-to-face most of the time, may need technical support and guidance on how to create an engaging and rigorous learning experience online. Universities and professional organizations should share what is working to support faculty and enhance students' learning experiences and outcomes.

We also recommend that universities and engineering units find ways to create smaller online learning communities. Though universities are stretched financially because of COVID-19, they must find ways to ensure that students have sufficient contact with faculty and each other. Options to do this include expanding peer-led small learning

Table 7. Recommended Learning Tools and Resources for Students

Resource	Purpose or Use of Resource	Web link
Khan Academy	To help understand engineering concepts	https://www.khanacademy.org
YouTube Videos	To find examples of how to solve problems	https://www.youtube.com
Symbolab	For step by step demonstration of how to solve calculus problems	https://www.symbolab.com
Desmos	As a free graphing calculator	https://www.desmos.com
Learn ChemE	To learn chemical engineering concepts and problem-solving demos	http://www.learncheme.com
Clutch Prep	For learning, chemistry, biology, and mathematics concepts	https://www.clutchprep.com
Grammarly	To assist with writing assignments	https://www.grammarly.com
SmallSEOTools	To review writing assignments for plagiarism	https://smallseotools.com

or study groups [90] and additional office hours. Universities might create incentives or offer faculty support to open up more office hours and spend more time on online advising and mentoring. In terms of student retention in STEM, time spent with students building relationships and cultivating a sense of community is time well spent. Relationships and community are particularly important for underrepresented students, who are the least likely to have strong communities within STEM [42, 44, 46, 47] and are the most likely to be struggling during COVID-19 [91].

Last, we offer a list of free online resources (Table 7) that may be useful for engineering students studying remotely.

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6. Conclusion

Our study offers the first glimpse into the state of undergraduate engineering education in the U.S. in the wake of the COVID-19 outbreak. We highlighted how universities, engineering units, and engineering faculty responded to campuses’ closure and the move to online learning. We also identified some of how undergraduate engineering students were struggling with the impact of COVID-19. Drawing on existing literature on engineering education and online learning, we clarified the contribution our study makes and offer recommendations for future research and faculty and university leaders.

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Appendix A

Location of Faculty Respondents

State	Percent of Respondents
AR	0.5
AZ	2
CA	7.1
CO	1.5
CT	1
FL	2
GA	3
IA	1
ID	0.5
IL	2
IN	4
INT	2
KS	0.5
KY	1
LA	2.5
MA	2
MD	1.5
ME	0.5
MI	3
MN	2.5
MO	1.5
MS	0.5
NC	2
NE	0.5
NJ	5.1
NM	0.5
NY	1.5
OH	3.5
OK	1.5
OR	4.5
PA	6.1
PR	1
SC	1
TN	3
TX	15.2
UT	1.5
VA	3
VT	1
WA	0.5
WI	3
WVA	0.5
WY	2.5

Location of Unit Leader Respondents

State	Percent of Respondents
AK	4.5
GA	4.5
IL	4.5
KY	9.1
LA	4.5
MD	4.5
MN	4.5
NJ	4.5
NM	4.5
OK	4.5
SD	4.5
TX	31.8
VA	9.1
WA	4.5
Total	100

Virginia Snodgrass Rangel is an assistant professor in the Educational Leadership and Policy Studies department at the University of Houston. Her research focuses on access to and persistence in the K-16 STEM pipeline, with a particular interest in the development of motivational beliefs among underrepresented students and the structural and institutional predictors of persistence in the STEM pipeline.

Jerrod A. Henderson is the Director of the Program for Mastery in Engineering Studies and instructional associate professor in the Cullen College of Engineering Chemical & Biomolecular Engineering Department. Henderson's work focuses on engineering student success, the lived experiences of Black male engineering students, and the development of out-of-school STEM interventions for underrepresented K-12 students. Henderson is a co-founder of the project described here. For his work he has recently been recognized as an Inspiring Leader in STEM by Insight into Diversity Magazine (2017), a Young Alumni Achievement Awardee by University of Illinois (2019); and a Science Spectrum Trailblazer Awardee at the 34th Black Engineer of the Year Awards (BEYA) STEM Conference (2020).