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Exploring the Impact of the COVID-19 Pandemic on the Lives of Engineering Students at San José State University, USA*

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In 2020, the College of Engineering at San José State University (SJSU) conducted a comprehensive analysis of the impact of COVID 19 on student learning and achievement. The purpose of this study is to assess the impact of COVID 19 on engineering students at SJSU. This study was a combination of a quantitative survey and a qualitative study. In Part 1, we surveyed all engineering students about their experiences after the move to 100% online instruction in March 2020. In Part 2, we interviewed 40 students to get more insight into their experiences during the move to online in Spring 2020. Overall, 993 students participated in the survey, 64% male and 34.5% female. The students reported feeling worse or much worse in several areas including time management (58.6%), ability to socialize with fellow students (86.1%), ability to socialize with friends (77.7%), and their overall psychological well-being (65.3%). Also, 79% of students reported either a moderate or a great deal of stress related to the shelter in place. This finding of increased stress was also emphasized in our interviews with the students. It is troubling since it indicates a declining mental well-being of students. SJSU engineering students were pessimistic about the next few months, Fall 2020, and their long term plans. We were able to get valuable information regarding effective methods of online teaching and areas where the students struggle the most. We will use this information to improve online teaching and student support in the upcoming semesters.

Keywords: COVID-19; online teaching; student wellbeing; student survey; interviews

1. Introduction

The quick move to 100% online instruction among universities in the United States in Spring 2020 brought with it a plethora of articles, essays and "best practices" for online instruction. One can imagine a professor faced to teach online for the first time being overwhelmed with the online teaching experience as well with the advice being offered. The decision to offer a newly online class in a synchronous or asynchronous mode was a complex decision faced for the first time by the majority of teaching faculty.

There has been research done on the effects of quarantine on individuals [1]. This is a contributing factor for both students and faculty. Brooks et al [1] conducted a review of the literature on the psychological impact of quarantine. After their review, the authors found that most research studies "reported negative psychological effects including post-traumatic stress symptoms, confusion, and anger" [1, p. 912].

1.1 Research on Students During COVID

Over the past few months, there have been many surveys about the college student experience during the COVID portion of the Spring 2020 semester and the number of surveys are growing. MindWires [2] is keeping a list of student surveys on its website. Currently, they have links to 29 surveys that were completed as of May 2020. In this paper, the authors are going to summarize the surveys that are most relevant to the current research.

Digital Promise and Langer Research Associates surveyed a randomized nationwide sample of 1,008 undergraduates, 717 attending four-year colleges and 271 attending two-year colleges, whose classes were converted from in-person to online after the COVID-19 pandemic hit [3]. They found that student satisfaction after moving online was lower than for in-person classes. Before the move online, 51% of students were very satisfied with their classes; after the move online, only 19% were very satisfied with their classes. This finding agrees with another survey by Simpson Scarborough [4] of 513 students in March 2020 which found that, among college students who took the survey, "63% say online instruction is worse than the in-person instruction they received at their school" [4, p. 23].

The survey also asked students to rate various aspects of the newly online classes. The lowest rated aspect was "Your learning overall." 17% of stu-

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dents were very satisfied and 40% were satisfied with their learning after the move online in Spring 2020. The most significant challenge for students was staying motivated to succeed in the course after it went online – 79% of students cited this as a problem. The students also indicated the following as significant problems: finding a quiet place to work (55%), fitting online education with family and home responsibilities (54%), and not knowing where to get help in the course (54%). There were differences when comparing students by ethnicity. Latinx students reported more major problems after classes went online in comparison to non-Latinx students. More Latinx students cited fitting online education with family and home responsibilities as a major problem (27%) compared with non-Latinx students (12%). Also, Latinx students said finding a quiet place to work was a major problem (21%) compared to 12% of non-Latinx students. More Latinx students reported not knowing where to get help in the course as a major problem (24%) compared to 14% for non-Latinx students.

The Hope Center [5] distributed a survey which was completed in April and May 2020 by 38,602 students from 54 colleges and universities in 26 states. The researchers found that 66% of the students had job insecurity; 33% of students at two-year institutions and 42% of students at four-year institutions had lost at least one job because of the COVID-19 pandemic. There was a moderate to high level of anxiety in about half of the students. More troubling, about half of the students reported that they had a hard time concentrating on their schoolwork because of the pandemic. As in the Digital Promise [3] study, students reported issues related to fitting online education with family and home responsibilities. 41% of students at two-year colleges and 36% at four-year colleges indicated that they needed to care for family members during the COVID-19 pandemic.

A separate study that included focus groups of 102 students across the U.S. from 47 schools was conducted by GlobalMindED [6]. The 102 students were 38% African-American, 42% Latinx, 14% White, and 6% other ethnicities. 80% of the students in the focus groups did not like the new online learning experience. According to the researchers, "much of the dislike was attributed to lack of innovation or responsiveness from faculty, internet concerns or poor physical environment conditions for learning" [6, p. 15]. The study by these researchers agrees with the findings of the Digital Promise [3] study that shows that there were many problems in the online classes, particular for under-represented students. Students in the GlobalMind [6] focus groups indicated that their physical learning environments at home made learning difficult. Also, there were other priorities and responsibility at home that affected their learning. More than 50% of the students also said that faculty follow-up was poor.

Ithaka S+R, in partnership with 21 universities across the U.S., developed a student survey focused on institutional communications and support, curricular needs, safety and well-being, and fall retention [7]. 15,677 students completed the survey. Included in the survey questions were challenges for students. The student responses about these challenge agree with the Digital Promise [3] results. Students in the Ithaka S+R survey [7] rated the following activities as somewhat or very difficult for them: balancing family, school and household activities, time management, adjusting to online education, and finding a quiet place to work.

Another nationwide survey was conducted by the Higher Education Data Sharing Consortium (HEDS) [8]. More than 42,000 students from 65 colleges and universities participated in this survey. 48% of students reported a great deal of stress because of COVID-19. Students in this survey indicated several worries including doing well in college, accessing and using the technology required, paying bills, and having a safe place to sleep at night.

The findings from the HEDS survey [8] agree with the survey by Top Hat of 3,089 college and university students across the U.S. completed in April 2020. Top Hat [9] found that students had difficulties in adjusting to the newly online classes in Spring 2020. The three highest areas were: lack of an engaging experience (78%), lack of face to face (Ftf) interaction with faculty and students (75%), and not having a quiet and reliable place to study (62%). 52% of the students reported feeling anxious and 36% did not enjoy online learning.

Daniels, Das, Hamza, and Leydier [10], working at Georgetown University's gui2de network, created a student survey which was sent to faculty and students across the world. In a preliminary report on this survey, published in May 2020, the researchers found that of the students who completed a question on their psychological wellbeing, 79% reported feeling worse or much worse after the COVID-19 pandemic started than they felt before. "78% say that their ability to pursue their academic goals (including, potentially, graduating) is now worse or much worse. Concerns range from more immediate concerns about graduation, online classes and examinations to problems with how to continue research for graduate students" [11, p. 5].

There were two statewide surveys of college students in California. The California Student Aid Commission [12] focused its survey on college

students and high school seniors in California over two weeks in May 2020. 76,000 students (60,000 college students and 16,000 high school seniors) completed the survey. For college students in California, COVID-19 had serious effects. 71% of students lost some or all of income and 46% of the students had a change in their living arrangements. More troubling for student success efforts, 24% of students dropped one or more courses in their spring 2020 college term. The survey also documented increases in student stress and worrying about their lives and finances.

The second California statewide survey, done by the Student Senate for the California Community College System [13], surveyed students to better understand the challenges they are facing and to better advocate on their behalf. More than 1,690 students from 64 California community colleges responded. Most of the students (67%) indicated that "were experiencing a higher level of anxiety, stress, depression, and/or any other mental distress than usual" [13, p. 7], 45% reported loss in income, and 26% indicated that they were dropping one or more classes.

1.2 Research on Engineering Students

Online education has been making inroads in several universities; however, the use of online education varies by discipline. The U.S. Department of Education [14] reported that, as of 2013, over 5.5 million students were taking at least one online post-secondary course. Distance education courses are less frequent in engineering. Only 24 universities, accredited by the Accreditation Board for Engineering and Technology (ABET), offer 100% online degrees [15].

Despite the increasing acceptance of online education by students and some faculty [16], this has not led to an increase in the number of engineering courses offered online. Because engineering courses are perceived by many students to be "difficult," surveys of students indicate that students prefer to take these courses in a F2f mode rather than online [17]. Also, according to Martinez, Aguilar, and Ortiz [18], online education is present mostly at the master's and graduate levels in engineering. At the undergraduate level, online education usually is limited to a few course in each engineering discipline.

This current study was done at San José State University (SJSU), a campus in the California State University (CSU) system. SJSU, as an institution, completed a survey of the impact of COVID-19 on all students at SJSU [19]. Of the 33,685 enrolled students in Spring 2020, 4,571 students completed the survey. Students indicated some concerns about their move to online instruction. Only about half of students reported being satisfied with the newly online courses and 57% of undergraduate students and 42% of graduate students reported that stress had impacted their academic success in Spring 2020 a lot. It is of concern that 30% of undergraduate students and 20% of graduate students did not have regular access to a place for studying and doing their courses.

In the literature, we found only two other studies focused on the impact of COVID-19 on engineering students. Another campus in the CSU, CSU Long Beach, conducted a survey of engineering after the move online in Spring 2020 [20]. They received completed surveys from 110 faculty and 627 students from six engineering departments at CSU Long Beach. The researchers found that students had several challenges with the online instruction during Spring 2020. "About 70% of students indicated difficulty in maintaining their focus or experiencing Zoom fatigue after attending multiple online sessions. 55% of students felt social disconnection from their classmates/peers, while 64% did not feel engaged during the online classes. 60% of the students felt there was a lack of clear guidance or communication from the instructors" [20, p. 4]. A second survey focused on engineering students was done at the University of Bacau, Romania [21]. 135 students (including 99 students from engineering) completed the survey. Overall, they found that students (59.2%) wanted more flexibility in online classes. Also, students reported it was difficult for students (47.4%) and faculty (34.8%) to adapt to this way of learning.

In our search of the literature, we found only one published study with interviews of students about their experiences during the COVID-19 pandemic. A group of Texas researchers [22] conducted an interview study at a large university in Texas. Despite being a survey of all students, 60% of the students were majors in the college of engineering. Of the 195 students interviewed, 71% indicated increased stress and anxiety and 89% reported difficulty in concentrating. With reference to their academic performance, 82% were concerned about their academics being affected by the pandemic with the biggest challenge being the move to 100% online classes (38%); students were concerned about changes to the syllabus, the quality of their classes after the move online, technical issues with online instruction, and the difficulty in learning 100% online.

Our SJSU student body is racially and ethnically diverse and reflects the demographics of our service area. Thirty percent of SJSU undergraduates are the first generation in their families to attend college, which is up from 24 percent five years ago. 8,978 (32%) undergraduate students in Fall

2019 were eligible for Pell grants – this is the indicator that we use for low income students. SJSU is an institution that educates many economically disadvantaged students (with family incomes below the national median) for an affordable tuition, and graduates them into good paying jobs. SJSU is ranked fifth in the nation on the Social Mobility Index [23] which measures the extent to which a college or university educates more economically disadvantaged students at lower tuition and graduates them into good paying jobs. At SJSU, our largest URM group at the undergraduate level is Hispanic students; indeed, we are a recognized Hispanic serving institution (HSI).

2. Methods

The results in this paper are part of a larger study completed at SJSU which looked at the impact of COVID-19 on students and faculty [24–28]. This current article has two sections: a student survey and student interviews. This section describes the methods our team used to recruit participants, survey them and conduct student interviews.

2.1 Research Questions

1. What are the impressions of students to the learning environments in engineering courses after the switch online in Spring 2020?
2. How is stress/anxiety contributing to learning outcomes among undergraduate and graduate engineering majors at SJSU because of the abrupt shift from in-person learning to online learning due to COVID-19?
3. What recommendations did students for faculty to improve their online classes in Fall 2020?
4. What was the impact of the switch online in Spring 2020 to project-based classes and lab classes?

2.2 Student Survey

For our student survey in this study, we looked at the questions that were developed by the researchers at Georgetown [10, 11] and HEDS [8] to develop our own student survey. Because many of the engineering classes at SJSU include laboratories, projects or other group experiences, we wanted to create our own survey to ask students about these experiences. The survey was reviewed by the Associate Dean of Engineering at SJSU. The College of Engineering dean's office agreed to give us a list of the emails of all Spring 2020 engineering majors who took at least one course in Spring 2020.

The SJSU team submitted an IRB application and it was approved on 5/28/20. There were 6,674 students who were enrolled as engineering majors in Spring 2020; each of these students was sent the survey through Qualtrics. The first email with the survey was sent on 6/1/20 with follow-up emails on 6/7/20, 6/15/20, 6/21/20, and 7/3/20. The survey was closed on 7/16/20.

2.3 Student Interviews

One of the last questions in the survey asked for volunteers to participate in an interview. 129 students volunteered to be interviewed as of June 30, 2020. Because of the high number of volunteers, we went through the students that volunteered for the interview and picked four students per major (if there were at least 4 volunteers).

The strategy we followed was as follows:

1. If volunteers < 4, we took them all.
2. If > 4, we divided them in three categories (1: Freshmen + Sophomore +Junior, 2: Senior, 3: Grad) and picked one student for categories 1 and 2, and two students from the graduate students. To do so, we assigned them a random number between 0–1 and picked the student with highest number for each category.

Overall, we chose 50 students to be interviewed based on the student survey data on June 30, 2020. We contacted the students by email and set up Zoom meetings in July and August 2020 to interview the students who replied. 26 of the 50 students set up Zoom interviews with one of the co-authors. After we closed the student survey on 7/16/20, we downloaded additional students (28 in all) who had agreed to be interviewed. We decided to replace the students who did not reply to our emails with other students who had agreed to be interviewed. In our replacement, we looked at four variables: grade level, major, gender, and ethnicity. Our first choice was to replace a nonresponsive student who matched on all four variables and our second choice was to replace a nonresponsive student who matched on three of the four variables. We included the student volunteers from 7/1–7/16 in our replacements for the student interviews. Table 1 shows the distribution of our student pool from the initial selection to the final selection. Overall, we completed interviews with 40 engineering students.

2.4 Student Interview Protocol

For this interview, our interview protocol was informed by the one used by Pawley [29]. The interview recordings were completed through Zoom and recorded on the Zoom cloud. When this is done, Zoom automatically creates a transcript of the Zoom video. The transcripts were reviewed by graduate students for typos in the transcript and words that the electronic transcriber misheard or misunderstood. Dr. Backer then pseu-

Table 1. Distribution of Students Selected to be Interviewed

	Original	Revised 7/17/20		Original	Revised 7/17/20
Female students	16	15	Freshmen + Sophomore + Junior	13	13
Male students	34	34	Senior	13	14
Other		1	Graduate	23	22
			Other		1

donymized the transcript, masking names, places, ages, organizations, ethnic groups (replacing them with broader racial categories), nationalities, languages, and religious affiliations or communities for those participants who desired it and the names of people participants mentioned. Dr. Backer sent the participants the pseudonymized transcripts to review for inaccuracies or things they regretted saying, and made the changes they requested. The interview consists of a single question: "How did you do in your classes in Spring 2020?". According to Pawley [29], this allows "participants to tell their stories in whatever way they chose" [29, p. 18].

We have included the prompts below for this interview protocol.

Interview guide

1. How did you do in your classes in Spring 2020?

   Prompts as needed: Tell me a little about yourself. Tell me about your experiences at SJSU after the transition to 100% online instruction. How did your instructors teach your engineering classes after going online? Has COVID 19 made any impact on your life? Did you take any lab classes? How did they go?

2. Prompts on institutional structures – financial, community service, student support, rules and regulations at SJSU.

   Generic prompts: Let's talk about that for a minute; Tell me more about that; So, just to clarify. . . How did you learn about this? What was important to you? Any regrets? Anything you wish you had done differently? Anything else you would like to tell me?

As discussed above, the interviews were conducted using Zoom. After the transcripts were cleaned and approved by the interviewee, we analyzed the transcripts. We used NVivo 12, a qualitative data analysis tool, to code response and identify outstanding themes of perceived in the student and faculty interviews. Interview data was coded via grounded theory approach and analytical domains based on the designated goals and objectives. Dr. Backer first hand-coded the interview data transcripts and then employed a coding scheme in order to look for emergent themes or domains of meanings or meaningful patterns across the interviews. The student interviews were independently coded by a graduate student. The two coders compared the coding and themes and agreed to the final coding.

An iterative inductive stage involved several close readings of the transcribed interviews by these two members of the research team who coded the results. This reading provides a holistic perspective of the responses. In this stage, points of interest and interpreted significance were coded by the team. At this point, both Dr. Backer and the graduate student coded the same transcript and then their results were compared and arbitrated. This process was continued until the coders achieved a valence of consistency that approximated near complete calibration. Then, each coding team member completed the rest of the transcripts individually, the project files were merged and one final arbitration session was conducted prior to moving to analysis stage.

3. Results

3.1 Student Survey

Overall, 993 students participated in the survey, 64% male and 34.5% female. 34.6% of the students stated that they are first generation college students. The grade levels of the students were: 41% graduate students (MS), 28% seniors, 20% juniors, 6% sophomores and 5% frosh. Hence, the majority of the students taking part in the survey were upper division and graduate students who take mostly upper division engineering courses.

3.1.1 Student Wellbeing

12% of the students declared that they currently had to take care of children or elderly. The majority of the students, 77%, indicated that they lived in the San Francisco Bay Area during the shelter in place. 70% of the students indicated that they will remain the San Francisco Bay Area even if the classes will remain online in the Fall semester.

A majority of the students (57%) indicated that their psychological wellbeing is worse than before. There were no significant differences between males and females and between students who were first generation and students who were not first genera-

Table 2. Student responses to the question: *Overall, how much stress are you feeling about the consequences of COVID 19?*

	A little or no stress	**A moderate amount of stress**	**A great deal of stress**
Students who sometimes or always have to take care of a family member	15.1%	44.8%	40.1%
First generation student	21.8%	46.2%	32.0%
All students	20.9%	52.3%	26.8%

tion. The students also rated their time management, ability to socialize with their fellow students, ability to socialize with their friends and connection to peers worse than before.

Overall 27% of the student population felt that they are under great deal of stress. Female and male students showed roughly the same percentage. First generation college students experienced elevated levels of stress compared to the overall student population. The one student population that showed significant increase in the amount of stress were those who took care of children or elderly in their household, 48% of these students stated that they were under a great deal of stress (see Table 2).

3.1.2 Availability of Resources and Space

In terms of availability to resources and space, the majority of the students (94%) has access to an electronic device (computer, laptop, tablet) and used it for their studies. In terms of internet access, first generation students have less access to reliable internet (77%) compared to the overall student population (85%). Students who needed to take care of a family member also has less access to reliable internet (75%) compared to the overall student population. The most dramatic difference between the overall student population, first generation students and students who need to take care of a family member arises when asking about available space for studying. Significantly, more first-generation students and students who were taking care of a family member do not have an adequate space to study. This automatically put them at a disadvantage compared to their peers when taking courses online.

When asked about how often do they worry about doing well in classes, accessing and using technology required for online classes, ability to do internships and their progress to obtain an undergraduate degree, the students' responses show that they worry the most about their ability to do internships and projects during their studies (see Fig. 1). This is related to the fact that the majority of the students that responded to the survey were juniors and seniors who have started to think about their career and job opportunities. Here, too, first generation students and students who need to take care of a family member worry more about all the items.

3.1.3 Online Instruction

Student responses to the question about the effectiveness of the online instruction varies (see Table 3). When asked about the effectiveness of the online teaching, most of the students indicates that most of their engineering instructors used effective meth-

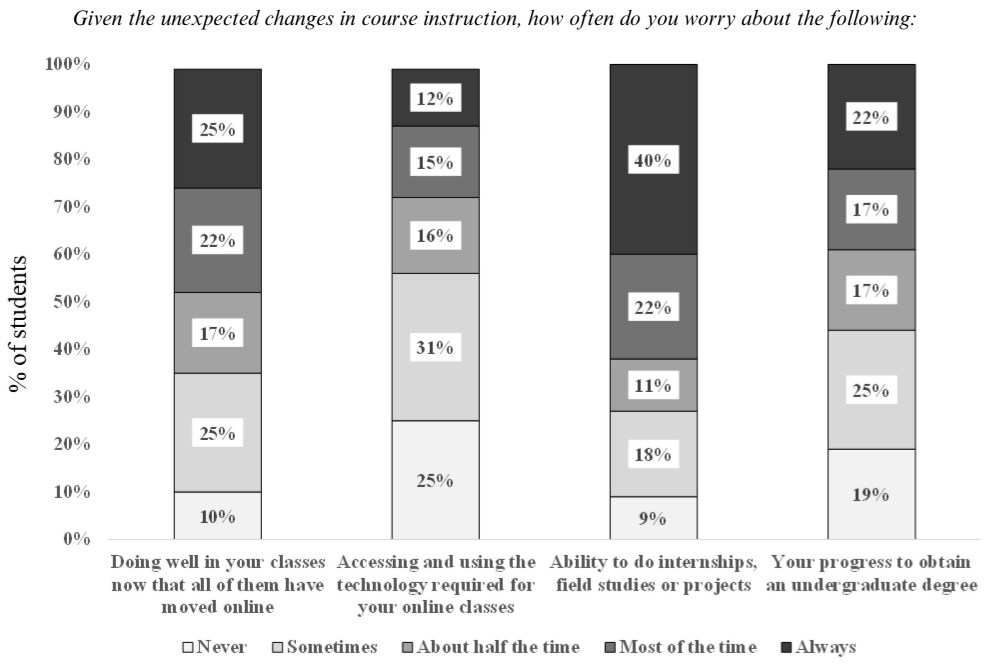

Fig. 1. Student responses to the question.

Table 3. Student responses to the question: *How effective was the instruction in your online engineering classes after March 2020?*

Effectiveness	Number	Percent
The instructors in all of my engineering classes used effective methods	171	26%
The instructors in most of my classes used effective methods	268	40%
The instructor in a few of my classes used effective methods	185	28%
None of my instructors used effective methods	42	6%

ods. From the students' free responses, it seems that they appreciate uploading the recorded lectures online. They appreciate the availability of the instructor and clear instructions regarding assignments and grading. Fig. 2 presents a comparison between the students' most successful and least successful engineering courses. From the students' responses, we can indicate that instructors in successful courses were able to establish an effective learning environment, used effective assessments and used teaching methods that helped the students to learn the important aspects of the course.

3.1.4 Testing and Lab Courses

79% of the students indicated that at least one instructor in their engineering courses used a controlled testing environment (LockDownBrowsers, ProctorU, ProctoRio). From the student responses, it can be seen that the students experienced elevated levels of stress (92%), had concerns about their privacy (83%) and felt distrusted by

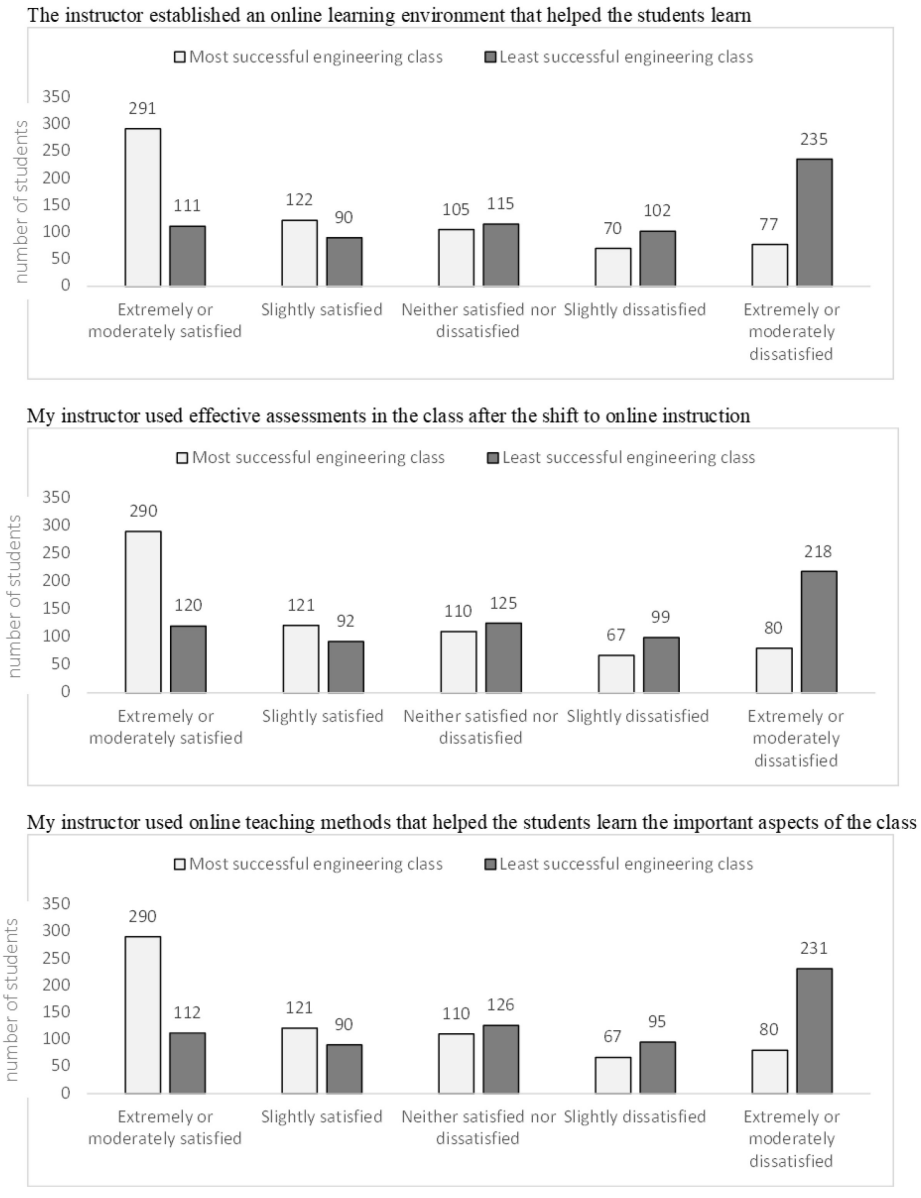

Fig. 2. Students response to the comparison between their most successful and least successful courses.

the instructor (81%). It is important to note that the students did not go through any training regarding the controlled testing environment. A training or workshop about the controlled testing environment might have helped in eliminating some of the anxiety that the students felt. Approximately 40% of the students indicated that they were enrolled in at least one lab course. For a successful engineering lab course, the students indicated that the instructor created online simulations or demonstrations to take the place of the in-person labs.

3.2 Student Interviews

The student interviews were conducted in July and August 2020 by one of the authors in this study. Overall, we interviewed 40 students using Zoom. To pseudonymize the students and protect their identities, we used the list of 2018–2020 Atlantic Hurricanes to rename the participants [30]. The names alternate from male to female and we followed the same procedure. Because we interviewed 40 students overall, we used the hurricane names from 2018–2020. Table 4 shows the majors, ethnicity, year, and gender of the students whose transcripts

Table 4. Students interviewed about their experiences in Spring 2020

Pseudonym	Major	Ethnicity	Year	Gender
Joyce	Aerospace Engineering	Two or more ethnicities	Lower Division	Binary
Fernand	Aerospace Engineering	Latinx	Upper Division	Male
Sebastien	Aerospace Engineering	Asian American	Graduate	Male
Tony	Aerospace Engineering	Latinx	Graduate	Male
Debby	Aviation	White	Upper Division	Female
Michael	Aviation	Two or more ethnicities	Upper Division	Male
Ernesto	Aviation	White	Upper Division	Male
Nadine	Biomedical Engineering	Latinx	Lower Division	Female
Sara	Biomedical Engineering	International	Graduate	Female
Kirk	Biomedical Engineering	Two or more ethnicities	Graduate	Male
Gordon	Chemical Engineering	White	Lower Division	Male
Florence	Chemical Engineering	White	Upper Division	Female
Arthur	Civil and Environmental Engineering	Asian American	Upper Division	Male
Patty	Civil and Environmental Engineering	Latinx	Upper Division	Female
Andrea	Civil and Environmental Engineering	International	Graduate	Female
Leslie	Civil and Environmental Engineering	Middle Eastern	Graduate	Female
Barry	Computer Engineering	Latinx	Upper Division	Male
Humberto	Computer Engineering	Latinx	Upper Division	Male
Van	Computer Engineering	Asian American	Graduate	Male
Valerie	Computer Engineering	International	Graduate	Female
Helene	Electrical Engineering	White	Upper Division	Female
Isaac	Electrical Engineering	White	Lower Division	Male
Lorenzo	Electrical Engineering	International	Graduate	Male
Nestor	Electrical Engineering	International	Graduate	Male
Chantal	Human Factors/Ergonomics (in ISE)	Decline to state	Graduate	Female
William	Industrial & Systems Engineering (ISE)	Latinx	Upper Division	Male
Pablo	Industrial Technology	International	Upper Division	Male
Dorian	Industrial Technology	Latinx	Upper Division	Male
Gonzalo	Industrial Technology	African American	Upper Division	Male
Jerry	Industrial Technology	Latinx	Upper Division	Male
Alberto	Materials Engineering	White	Graduate	Male
Oscar	Mechanical Engineering	Middle Eastern	Lower Division	Male
Cristobal	Mechanical Engineering	African American	Upper Division	Male
Edouard	Mechanical Engineering	African American	Upper Division	Male
Erin	Mechanical Engineering	Asian American	Graduate	Female
Gabrielle	Mechanical Engineering	Asian American	Graduate	Female
Rafael	Mechanical Engineering	Middle Eastern	Graduate	Male
Chris	Mechanical Engineering	White	Graduate	Male
Imelda	Software Engineering	African American	Upper Division	Female
Beryl	Software Engineering	White	Graduate	Female

we analyzed for this study. One student's transcript was not included because the student did not take any engineering classes in Spring 2020. Instead, this student only took classes for a business minor.

We interviewed students from each major in the SJSU College of Engineering with the exception of students from General Engineering. General Engineering is the smallest program in the college; in Spring 2020, there were only 73 students in General Engineering of the 6,372 students in the college overall. Only six General Engineering students responded to the survey and one of these students volunteered to be interviewed. However, he did not respond to the email request to set up an interview.

We divided the students into three groups: lower division students (Freshmen and Sophomores), Upper Division students (Juniors and Seniors) and Graduate students. As described in our methodology section, we purposely used a stratified approach to our selection of the interviewees so that we would get representation from all of the departments.

After the transcripts were coded using nVivo 12 software, we evaluated the frequency of the coding. Overall, we generated 35 different codes based on the student interviews. Table 5 shows the codes, the number of student interviews with the code, and the number of total references. The highest theme that was present was "negative experience." 32 of the 39 students who were interviewed indicated that they had at least one negative experience in the Spring 2020 semester related to their engineering classes. The next highest codes were "project work" in Spring with 28 student interviews including this code and online tests and exams with 27 student interviews including this code. Interestingly, the next highest code was "positive experience" with 25 student interviews including a positive experience in the Spring. The closeness of negative experiences and positive experiences show the dichotomy for many students about the Spring 2020 semester. For most students, they had classes and instructors that did a good job and others who did not.

In reviewing Table 5, we saw that most of the codes were related to negative comments by students related to their experiences in Spring 2020. The second most common category were comments related to student comments related to class content. The other categories were recommendations for improving instruction, student positive comments, student personal experiences in Spring, and other comments. We will discuss each of these categories separately in this analysis.

3.2.1 Student Sentiments

During the interviews, the students were direct in discussing their concerns about the instruction during Spring 2020. Almost all of the comments under Negative Experience dealt with the students' experiences with their classes in Spring 2020. 32 of the 39 students interviewed had at least one negative experiences in Spring 2020 after instruction went online. Some of the comments related to the way the class were taught, other comments related to office hours, and others related to online testing. There was a lack of communication for many professors as noted by Fernand – "We had not much communication with the professor for almost a month. I'm not sure what happened to the professor." Also, many students commented on the lack of engagement in the class and lecturing the entire period – Chris noted "And this professor, he isn't, he doesn't have the best technological understanding to begin with you were in person. Doing PowerPoints, and stuff was kind of hard. But I feel like the main problem he ran into was he didn't really take advantage of the tools that were available to them. He did not use Canvas."

At the same time, many students reported positive experiences in their classes after the move online in March 2020. Overall, 25 of the 39 students reported a positive experience. The positive experiences were reported by the same students who had negative experiences. These positive experiences were related to the ways that the faculty conducted classes as well as supports that the faculty members gave the students. Student appreciated when faculty members recorded their presentations as many students had intermittent connectivity issues. Erin noted that one of her professors "recorded his screen. He went through a PowerPoint on the screen and wrote on something similar to a whiteboard on his screen, where applicable to solve problems. . . He would record it, uploaded on canvas, and then we could access it at any time and just view it as a video within canvas." To highlight the comments made under negative comments, students appreciated when faculty gave clear instructions. Jerry commented on this issue – "We had dates for everything in class when we had our zoom meetings, she explained that all the dates all the cutoff dates, whether or not there's any leeway."

3.2.2 Student Comments Related to Course Content

The largest number of student comments related to course content including project work in the Spring 2020 semester (28 students), online tests and exams (27 students), lab issues (23 students) and PowerPoint use and issues (13 students). As can be expected, both projects (most of them group projects) and lab work was challenging for the students and instructors after the quick move online in March 2020. Despite the challenges, most of the

Table 5. Frequency of Coding in the Spring 2020 Student Interviews

Code	Number of Student Interviews	Number of Total References
Student Sentiments		
Negative Experience	32	89
Positive Experiences	25	47
Student Comments Related to Course Content		
Project Work in Spring	28	41
Online Tests and Exams	27	75
Lab Issues	23	40
Powerpoint usage and issues	13	18
Student Recommendations for Improving Instruction		
Recommendations for faculty	20	32
Instructors should be better organized and be able to use technology	13	14
Classes could be more interactive	9	9
Videos should be available after class	9	14
Instructor refused to record or post lectures	9	12
Student Negative Comments		
Instructor lectured the entire period	18	33
Instructor did not respond to emails from students	13	19
Instructor did not conduct classes after COVID/instructor missed several classes	7	11
Instructor did not hold office hours	7	10
After COVID, classes were (should be) more flexible	8	10
Instructor could be more understanding	5	6
Instructors want students to work more	4	4
Instructor thought students were cheating	4	4
Students cheated	3	4
It was hard to talk to instructor during office hours	3	4
Class did not meet at scheduled time	1	2
Student Positive Comments		
Instructor used active learning	16	24
Instructor responded to students via email or in office hours	9	11
Instructor tried very hard in the online class or used Canvas effectively	6	7
Instructor used a whiteboard	4	5
Students Personal Experiences in Spring		
Spring was a lot of stress	20	34
Students miss social interactions and work with other students	12	20
Student did not like online learning	9	14
Important thing is to reduce risk from COVID	9	10
Student needs to be more proactive in online classes	8	9

students were able to complete their projects after the move online. As Leslie noted, ''We had yeah we had projects in both classes, we presented them over Zoom. We would put up the PowerPoint and then present like normal.''

The main issue with project work was related to the senior projects for most of the engineering majors. At SJSU, most seniors complete a two-course sequence for their senior projects. The Fall semester is focused on designing and the Spring semester is dedicated to the building of the project. Many groups did not finish their senior project work before the move online in March 2020. Fernand's experience in his senior project was echoed by many other students we interviewed. ''I think spring semester was something that a lot of us in the aerospace engineering lab had a tough time dealing with since a lot of us have projects going on, and a lot of a lot of it was coming to fruition, but then spring came with the coronavirus and it just derailed everything.''

Approximately two-thirds of the students reported issues with labs after the move online in Spring 2020. Many instructors either omitted the labs from their classes or did the experiments themselves and shared the results with the students in the class. Also, there were many issues related to online tests and exams. Overall, very few students enjoyed the online tests. Oscar summarized this point in his interview. ''So most of them (the tests)

were pretty long. So, a lot of us students didn't even finish like the last few questions. And the way he had it is like the beginning is like the multiple choice, and then the end are like the long, you have to type out the code. So it was a little like rushed at the end always." The tests ranged from take-home exams to proctored exams using lockdown browsers. Students felt that faculty did not adapt their tests to an online environment well and the students disliked lockdown browsers. Valerie, among other students, had difficulties with the lockdown browser tests. "Many students faced challenge with the ProctorU exam, due to technical difficulties they were not able to begin exam for about an hour. . . During ProctorU exam, we were not able to communicate to our professor to ask any doubts in the question, I lost 12 points in one of the midterm exam, because I accidently closed the ProctorU chat window and got panicked whether university not able to monitor me and what if my exam got invalid. So clicked submit exam before completion."

Students had mixed feelings about the use of PowerPoint in their classes after the move online. From the interviews, it appears that many instructors used PowerPoint for their entire class time after the COVID 19 shutdown. Students had difficulties following the instruction from faculty who lectured for the entire period online.

3.2.3 Student Recommendations for Improving Instruction

Most students appreciated the efforts that faculty made in the quick transition online. The students expressed concerns about the organization of the classes (13 students), the lack of interactivity (9 students) and the availability of lecture videos (9 students). More than half of the students gave recommendations as to how faculty could improve their online classes in Fall 2020. Many faculty, according to the student interviews, were unprepared to teach online. They had difficulties in using the learning management system (LMS), Canvas, as well as Zoom. As well, some faculty would not record their lectures or not post them online. As some students had Internet connectivity problems, this was a problem for students. Approximately 1/3 of the instructors did not or would not post videos.

3.2.4 Student Negative Comments

Not surprisingly, considering that most students expressed at least one negative sentiment, the largest number of different comments were negative. A large number (18 out of 39 students) reported that, in at least one of their classes, instructors lectured the entire period. Most classes at SJSU are scheduled for either twice a week for 75 minutes or once a week for 2.5 hours so this required students to sit watching lectures for the entire time.

When faculty lectured all or most of the period online, the students desired more interaction or active learning. A recommendation from Gonzalo was to embed active learning in the online classes. "So I'd suggest having like an after class quiz asking the students on how they're understanding it. So like what gets students to think ahead of what they're about to show in the class, things like that that'll keep people engaged."

Approximately, one-third of the students responded that their instructors did not respond to emails from students. SJSU has many part-time lecturers in the College of Engineering so this issue was compounded by the fact that many part-time instructors, particularly in the Masters programs, are working professionals. The loss in communication between the instructors and students was shown also in the number of instructors who did not hold office hours after the switch to online instruction in Spring 2020. According to SJSU policies, full-time instructors must hold 3 hours of office hours each week; the amount of office hours is reduced for part-time instructors. The students felt this lack of communication deeply. Florence noted "On top of that, answering emails is a big thing for me like I had a professor in the spring quarter. He was really good about answering emails for a little bit and then towards the end. I would send him follow up emails like hey did you get this, and I never got a reply."

3.2.5 Student Positive Comments

Despite the general negative impressions that students had during Spring 2020, there were accolades for instructors who did well online. Over 1/3 of the students had at least one class that used active learning online (16 students). Some faculty used features in Zoom or Canvas to do active learning online while others had students complete group assignments during class. One of the examples was given by Fernand. "I do think she handled it well because the way she transitioned from in class to online, was she tried to keep the same format where she would present a new material, have us do some kind of example for five to 10 minutes of the class and then explain it. And then we move on and do something on MATLAB or, look at case studies examining earlier aircraft incidents nothing in depth but insightful."

3.2.6 Students Personal Experiences in Spring

More than half (20 students) reported that the Spring 2020 semester after the move online was stressful for them. There were many causes for the stress that students felt. Some undergraduate and

graduate students have children and, in California, all K-12 schools in our area went online in March also. This caused additional stress to students who now had to be the teachers for their children as well as being students themselves.

Students missed social interactions with other students. This was related both to classwork or group work with other students as well as activities on campus. SJSU moved online quickly in March 2020 and all campus events were cancelled and the facilities such as the Counseling Center and Student Center were closed. This left many students feeling isolated. Also, nine of the thirty-nine students interviewed did not like learning online. There were many reasons for this. Some students did not believe that they learned the same amount of content as they would have if the classes were in-person. Other students were concerned about the labs.

3.2.7 Overall Impressions from Student Interviews

The student interviews echoed the surveys we conducted and provided more context. The students struggled in many ways after the move online in Spring 2020. They had issues with the instructors' teaching, the online learning environment, and personal issues. The students felt that the instructors did not realize the impact of teaching the same way as they did in an online class. Also, the students believed that the instructors did not realize the stress they were under. Students hoped that the Fall 2020 semester would be better organized and conducted. Valerie summed up her feelings about the classes: ''One professor, only one professor, was like giving us the thought of, I mean having the opening talk of 'Okay, how are you people doing, how was the things with assignment. Do you need any extensions are you people doing okay?' The professor followed that practice of consent. He goes to ask us things are normal. 'Hope everybody have a Wi Fi connection. Hope you're doing well. Do you need any help for the extension of assignment?' and things like that. Only one professor did that.''

4. Discussion

Much of the results from our survey and student interviews agree with other research studies on the impact of COVID 19 on university students in Spring 2020. When asked about the effectiveness of the online teaching, the majority of the students in our survey indicate that most of their engineering classes were taught in an effective way. From the students' free responses, it seems that they appreciate uploading the recorded lectures online. They appreciate the availability of the instructor and clear instructions regarding assignments and grading. Fig. 2 presents a comparison between the students' most successful and least successful engineering courses. From the students' responses, we can indicate that successful courses had clear communication and directions about course assignments, the instructor was able to establish an effective learning environment and used teaching methods that helped the students to learn the important aspects of the course.

Our student interviews indicated that students had more negative impressions than positive ones about their experiences in Spring 2020 after the switch to online teaching. 32 of the 39 students interviewed had at least one negative experiences in Spring 2020 after instruction went online. Some of the comments related to the way the class were taught, other comments related to office hours, and others related to online testing. Overall, many students did not like online instruction. This agrees with the study by Means and Neisler [3] who found that student satisfaction after moving online was lower than for in-person classes. When we compared our results with another study on engineering students in the CSU [20], we found similar challenges for students. However, since we conducted in-depth interviews with 39 engineering students, we were able to expand on this research to provide a more nuanced analysis of the engineering student experience.

Overall, 27% of the student population felt that they are under great deal of stress. Female and male students showed roughly the same percentage. First generation college students experienced elevated levels of stress compared to the overall student population. The one student population that showed significant increases in the amount of stress are those who took care of children or elderly in their household, 48% of these students stated that they are under a great deal of stress. This finding agrees with several prior surveys of students during Spring 2020 including the HEDS [8] survey, the Student Senate for California Community Colleges [13] survey, and the California Student Aid Commission [12] survey.

The students surveyed gave many recommendations to faculty to improve the online learning experience. More than half of the students gave recommendations as to how faculty could improve their online classes in Fall 2020. Many faculty, according to the student interviews, were unprepared to teach online. They had difficulties in using the learning management system (LMS), Canvas, as well as Zoom. Also, some faculty members would not record their lectures or not post them online. As some students had Internet connectivity issues, this was a problem for students. The results show that approximately one-third of the instructors did not, or would not, post their lecture videos.

When asked about how often they worried about doing well in classes, accessing and using technology required for online classes, ability to do internships and their progress to obtain an undergraduate degree, the students' responses show that they worry the most about their ability to do internships and projects during their studies. This could be related to the fact that the majority of the students that responded to the survey are juniors and seniors who have started to think about their career and job opportunities. Here too first generation students and students who need to take care of a family member worry more about all the items. More than half (20 students) who were interviewed reported that the Spring 2020 semester after the move online was stressful for them.

5. Implications for Practice

This study has several implications for practice, particularly as related to instructional pedagogy. It is clear that faculty must create online instruction in a purposeful manner instead of porting the in-class experience directly to online classes. In Spring and Summer 2020, SJSU offered online pedagogy classes for faculty in the university. However, from the student comments in the interviews specifically, this training was probably not enough.

With COVID 19 continuing to affect future semesters, faculty need to rethink their courses so that they maximize interactivity and content. Students were willing to sit through entire periods of lecture in the in-person class mode but online these methods are less effective. Faculty tend to associate their joy in teaching with face-to-face interactions, failing to recognize ways in which those joyous moments could be transferred to an online environment. Faculty struggle to transition their joy and self-worth as an educator between pedagogies, including pedagogies necessary for online instruction. Table 6 summarizes the recommendations that students made for faculty to do and not do in online courses.

Table 6. Major Recommendations from Student Interviews for Faculty Teaching Online

Things Faculty Should Do	**Student**	**Advice from student**
Meet at the scheduled time	Erin	"I would recommend meeting at the same time as the classroom schedule. That was my only complaint last semester. The delivery of the instruction was unpredictable and inconsistent."
More interactivity (active learning) in online classes	Patty	"Example problems. I thought should have been worked out by hand, not just like a slideshow of it all already worked out and they kind of just walk through it. Just because it's already a lot of information and I liked being able to follow the instructor, step by step."
Record and post lectures online	Ernesto	"It wasn't like they do record them and post them if you like ask about it. But it wasn't set like okay, I'm just going to pre-record the lecture. And then you guys can watch it. It was just, 'I'm not going to record this zoom session that I expect you to attend'. And then if you're not there, then you have the zoom but I'd rather be able to just watch it on my own time."
Care for students	Oscar	"I feel like some of them, they're harder to stay motivated, but then some of them, like I feel like with all classes there's always professors who care more about the students and then all those professors who don't really care about the students too much."
Better communication	Issac	"So that kind of slowed them down and they were all very disengaged, because a lot of them had sent emails trying to ask about how things are changing and trying to talk about, you know, scores from exams that had happened before the transition and they just weren't getting responses."
Be better organized	Beryl	"But maybe, you know, maybe it may be instructor should be kind of more prepared for such kind of sessions, because it's different when you interact with students and when you actually just like doing via zoom."
Design online labs better	Gonzalo	"Half of the class was a lab and I didn't feel like I learned as much as the lab than the lecture. The lab was a very hands on type of situation and instead we basically watched a pre recorded video of the lab professor in the lab doing the system that we were going to intend to do during class..."
Things Faculty Should Not Do	**Student**	**Advice from student**
Don't use lockdown browsers for tests	Alberto	"The only thing I would mention is that striking a balance between privacy (invasive proctoring programs), too much faculty work(constantly having to remake tests/ homeworks/quizes without graders), or the possibility of disregard (ignore cheating, Chegg, etc.) for academic honesty will be a complicated challenge for the online experience."
Don't lecture the entire class	Valerie	"They just lectured like they were in class and they just pretended everything was normal and they lectured for the whole two and a half hours."
Don't rely too heavily on PowerPoint presentations	Rafael	"The online lectures for the master's program, they are pretty long. You know, like, because they do this two days per week and then two hours or sometimes three hours in one day, that i think i don't know like the professors need to be more creative or more Like find different ways for these lectures. Because two hours just watching the PowerPoint slides, we lose focus."

Online teaching faces difficulty in gaining respect from a professoriate who has little experience with it. Faculty spend years developing their expertise and credibility in their fields, with little preparation for instruction. Faculty tend to fall back on teaching the way they were taught, with relatively few of them having had an online experience. Very quickly, those who begin to teach online realize that online instruction is not as simple as moving the same in-person curriculum and content online [31]. Quality online instruction takes time and effort, both of which may be limited for probationary and part-time faculty.

Online instruction requires a set of skills as a teacher that many faculty have not learned. Again, faculty tend to teach with the same methods that they were taught without sufficient professional development that encourages and promotes new pedagogical skills. Professional development in academia often lags the state-of-the-art in pedagogical practice, often related to resistance to pedagogical advances and lack of time available to learn and practice new pedagogies, as discussed above. Universities interested in investing in online education must invest in preparing their faculty to transition to an online environment. Whether teaching in-person or online, faculty can use the results of the student interviews and surveys to reorganize their pedagogy and implement strategies like active learning in both in-person and online classrooms.

It is time for our engineering faculty to accept that online education is a viable alternative for in-class instruction. Witham, Malcom-Piqueux, Dowd, and Bensimon [32] outlined equity minded principles for improving outcomes for students from all backgrounds. Using equity minded strategies in the classroom can change an instructor's view from blaming the students for non-achievement to approaching pedagogical reform to provide "more just, equitable and effective learning environments for African Americans, Latinos/as, American Indians, and subordinated Asian and Pacific Islander populations" [33].

6. Conclusions

Teaching online has been viewed with suspicion by many faculty, even in the STEM disciplines. At SJSU, prior to Spring 2020, there were few engineering classes taught in a fully online mode. The educational crisis brought on by COVID 19 has led to a dramatic revision in the way that courses are taught, both at our institution and nationwide. However, best practices in teaching online have generally been passed over in the need to put a class online. It is time for our engineering faculty to accept that online education is a viable alternative for in-class instruction. As a Hispanic Serving Institution located in one of the most ethnically diverse locations in the United States, it is important for us to redesign our teaching to improve the outcomes for students from all backgrounds.

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