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Sudden Shift to Online Learning: COVID-19's Impact on Engineering Student Experiences

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Work in Progress: Sudden Shift to Online Learning: COVID-19's Impact on Engineering Student Experiences

Abstract

In light of the COVID-19 pandemic, engineering education has faced a shift to a partial if not fully virtual environment that has disrupted students' educational experiences. This qualitative study was designed to explore how mechanical engineering students at California Polytechnic University, San Luis Obispo have navigated the shift to virtual learning, what pedagogical practices have been effective online, and how the change has affected students' motivation, learning, and sense of belonging and community.

During an hour-long focus group, participants were asked to maintain anonymity by turning off their cameras and by using pseudonyms. They responded to open-ended questions related to teaching strategies, workload, motivation, lab courses, technology issues, building community, academic integrity, and general improvements they wanted to see in future online classes. Summaries were created and analyzed by the two student researchers and discussed among the research team. Further recommendations to professors were made categorized by which theme they applied to best.

For example, faculty were advised that students appreciated the effort they put into moving to a virtual environment with such short notice but commented that the quality of online learning could be improved. Our primary findings indicate that the key shortcomings included difficulty building community as well as decreased motivation levels and increased stress levels.

Background

With the emergence of COVID-19, all facets of life across the globe were disrupted and had to adapt to the unprecedented situation. In particular, schools faced a massive shift to online learning at every level of education. The stress of multiple rapid changes due to the pandemic and national current events has affected student learning in ways we are just beginning to understand. College curricula that heavily rely on hands-on learning and collaborative approaches, like engineering, have especially been impacted by this switch.

This study explores how engineering students have navigated the sudden shift to virtual learning, what pedagogical practices have been effective, and how it has impacted their motivation, learning, and sense of community. This research specifically examines mechanical engineering students' experiences at a large public university in California. At the end of this university's Winter Quarter, faculty were given two weeks of training and preparation during an extended Spring Break to develop their online curriculum for the upcoming quarter. Courses were offered in synchronous and asynchronous formats. Students were also given the choice to take an unlimited amount of class units with a "credit/no credit" grading system. For this new quarter, most course webpages were moved to Canvas, a course learning management system new to our institution.

Literature Review

Over the course of the past few decades, some institutions have created ABET-certified online engineering programs. These online courses have been phased in over many years, with significant infrastructural support. In contrast, the transition to online learning due to COVID

was abrupt and unexpected. For this reason, most universities that switched online due to the pandemic gave faculty great flexibility with how they could present their courses in an online format, which resulted in great variations in online course adjustments [3]. At most institutions, faculty were given a few days to a week to prepare for the shift to online learning. Although the time period was short, it allowed faculty to become familiar with technology and teaching methods they had little to no prior experience with. Generally, there was a learning curve when it came to using these online tools, as well as technical difficulties such as connectivity issues and printing and scanning [5].

The concept of "change readiness" [1] was especially important during the emergency transition, as many faculty members were unfamiliar with online teaching. Change readiness is defined as someone's "beliefs regarding the appropriateness of, support for, and value of a change" [1]. If unprepared for a sudden change, students and faculty could face negative feelings towards motivation and focus, which some researchers observed to occur at their institutions during the emergency transition period [4]. Some researchers noticed that motivation was directly linked to structure, which many students lacked during the emergency online learning transition period [2],[3].

Many researchers found that students appreciated instructor flexibility as well as understanding and accommodations when it came to late assignments and projects [3],[4]. Moreover, research showed that university-mandated grading changes—such as going from point-based to credit/no credit—was a tumultuous choice. While some students felt relieved that they no longer had to be concerned about their GPAs being negatively affected, others argued they worked hard for the grades they were supposed to receive and went to lengths such as starting petitions to overturn those grading decisions [5]. Some other issues faced included lack of adequate materials for labs, technical or software issues, and both faculty and student workload increase [3],[5].

The community and social interactions between students themselves and with instructors were reported to be heavily impacted due to this shift. Students who were used to working in teams or had already worked with their peers before the virtual shift did not face as much difficulty as students who were more unfamiliar with their peers [4]. For more interactions with faculty, there were reports of students requesting low-stakes, in-class assignments, office hours, etc. [3].

Evaluation and assessment were also a topic of concern with this shift to online teaching, as it can open a door to academic dishonesty and technical troubles administering online assessments. Strategies such as take-home exams, 24-hour exams, and lowering exam weights were considered and used by some institutions [5]. At one university, students suggested that instructors refrain from using multiple choice exams and focus on problem-solving questions to avoid cheating and academic dishonesty [4].

All of these themes are important to highlight with regards to improving the state of virtual education. Many of the topics uncovered by other researchers connect to our findings that will be defined and explored later in this paper.

Methods

In spring 2020, we recruited 31 Mechanical Engineering students to participate across seven focus groups, held between July 7th and July 16th. The 60-minute focus groups were held over Zoom™ and facilitated by two faculty members—Drs Brain Self and Lauren Cooper—at California Polytechnic University, San Luis Obispo.

Focus groups are purposefully planned discussion groups that aim to gather perceptions on a specific topic from a predetermined and limited number of people. Typically, focus groups are run by a trained moderator and include 4-10 participants. Because people are naturally influenced by the comments and opinions of others, focus groups can capture people's socially constructed thoughts, attitudes, and beliefs [6]. Inhibitions soften in a group setting, so focus groups can encourage candor as well as allow the researcher to explore unanticipated discussion issues [6]. To encourage honest and candid feedback, we required students to join the focus group using a pseudonym and to leave their webcams off. All focus group participants were volunteers who had the right to refuse to answer any question(s) and to withdraw from the study at any time. Participants received $20 Amazon gift cards as incentives.

During the focus groups, participants were asked to maintain anonymity by turning off their cameras and by using pseudonyms. They responded to the following open-ended questions related to teaching strategies, workload, motivation, lab courses, technology issues, building community, academic integrity, and general improvements they wanted to see in future online classes:

- *Think of your best or worst class this quarter. Briefly describe a typical class session and tell us if this was your "best" or "worst" class.*
- *What has your workload been like this quarter?*
- *What things did professor do online that were particularly effective?*
- *How have faculty tried to help you build community in your classes?*
- *What technology issues have you and your professors had?*
- *What types of virtual labs seemed to work well?*
- *What are some ways you think we could protect academic integrity?*
- *How was your motivation level this quarter?*
- *What suggestions do you have for improvements for fall?*

The responses and conversations from the focus groups were automatically transcribed using Zoom™ and were checked for accuracy by the two student researchers. Summaries of each focus group were created and analyzed by the two student researchers and discussed among the whole team, during which they discussed and identified the seven main themes discussed below.

Results & Discussion

During analysis, the following topics were developed as the emergent themes discussed among the focus groups:

- Course structure
- Lab courses
- Faculty influence on student wellbeing
- Student motivation
- Building community
- Technology and access
- Assessment and academic integrity

This section will present the findings pertaining to each of these themes and explore them further.

Course Structure

There were mixed responses when it came to preferences about synchronous and asynchronous classes. Students who preferred synchronous classes liked having the ability to ask questions in real time, and said that it was closer to traditional in-person courses. Students who preferred asynchronous courses liked them because it provided flexibility in their schedule, accommodated time zone differences, and allowed them to learn on their own time.

One asynchronous course in particular was set up uniquely: each student's grade was based on how many assignments were completed. This allowed students to choose topics that were interesting to them and complete assignments on their own time.

> *"I really liked how the course was graded. [It was] based off of completion of assignments... Basically if you did a certain amount, you get a C and then if you did, you know, five more you get a B, five more you get an A and so you got to choose which assignments [interested you]."*

Instructional videos, whether in asynchronous classes or recorded from synchronous lectures, were very helpful for students. Being able to speed up portions they already understood, pause to take notes, and to review at later dates were all beneficial. However, some instructors added more lecture content to their videos, requiring significantly more time than a face-to-face course would.

> *"Some of [my] teachers… put more videos in more time than it should have actually been allowed, so you'd end up watching like an hour class three times a week, and I was probably watching like 10 hours' worth of videos."*

It was also helpful to have lecture outlines to help students focus on the most important portions of the lecture. Having blank portions of note outlines for the students to actively fill out was also recommended by some students. Additionally, writing out notes or diagrams using a digital whiteboard can help students follow along and using animations in the slides can help students keep track of the content. Students said it was harder to pay attention during virtual classes, so course structures that can foster and maintain engagement is more conducive to student learning.

Recommendations for faculty are as follows:

- Provide lecture outlines or "note-takers" for each class session; consider including lecture learning objectives for each class.
- Post recordings of all Zoom™ class sessions.
- Update all assignment due dates and grades on Canvas™.
- Avoid overloading students with videos, too many technology tools (e.g., multiple simulation packages), or assignments that might be construed as busy work.
- Consider alternate forms of instruction and/or assessment that the virtual environment allows.
- In asynchronous courses, have intermediate deadlines to help students stay on track.

Lab Courses

Because engineering courses heavily rely on lab activities, they were already expected to face some difficulty when transitioning from in-person to virtual instruction. Students had mixed experiences with using simulations and online programs in place of lab activities. They ran into technical issues with some of the software, and did not like that it felt artificial.

> *"[The program we used is] basically just like a virtual lab website and it has a lot of bugs. It doesn't save, sometimes it just randomly won't work, and you have to redo your whole entire circuit. It was not very intuitive, and it was frustrating... [I was] frustrated the whole time."*

Students had good experiences with lab simulations when they successfully imitated an in-person experience. They also succeeded more with simulations when receiving guidance from the professor in the form of guided videos/Zoom™ lectures where they were either using the program or demonstrating what the in-person lab would be like.

> *"... In my EE lab [...] there was an online lab desk simulator, and it had all the components, you could add in and connect cables to all the ports. It was a really good like re-creation of an actual lab desk and so I felt like, even though obviously we weren't using the actual equipment, it was pretty similar. I thought that was a really good piece of software."*

Additionally, several students enjoyed the use of lab kits, which gave them a hands-on experience at home. However, some students may have difficulty accessing these supplies due to financial reasons, lack of availability ordering online, or being unable to find them in their local area. For example, low-income students might especially have less accessibility to these supplies because of having to pay out-of-pocket for them.

Students also liked working with lab partners or groups. When they had to work alone, it felt isolating and did not help with learning the material. Being able to work with lab partners/groups in breakout rooms and having the professor move between them during the class session was helpful for students because it allowed them to connect and interact with other students and ask the professor questions when they needed to.

> *"Breakout rooms were pretty good for synchronous labs. The professor was able to start off explaining everything to us and putting us into small groups and breakout rooms and you can just kind of pop back in the main room if you need help or had a question."*

Recommendations for faculty are as follows:

- Put students into lab partners or groups and facilitate student introductions with each other over Zoom™ at the beginning of the course.
- Provide lab videos that show students what they would be doing in an in-person course.
- Use simulation programs that effectively simulate what it would be like for students to take the lab in person.

- Update lab manuals for online instruction.
- Set up a special discussion form on Canvas™ or Piazza™ for students to ask questions about the lab.
- Keep in mind that many students are using virtual software they've never had to use before.

Faculty Influence on Student Wellbeing

The influence that faculty have on student wellbeing was acknowledged by many students across the seven focus groups. The COVID-19 pandemic as well as the Black Lives Matter protests and demonstrations related to the deaths of Ahmaud Arbery, George Floyd, Breonna Taylor, and many others, created an intense level of stress among students. They appreciated and needed their professors to acknowledge this stress and to respond accordingly. While few professors carved out time during class to discuss current events explicitly, many professors demonstrated flexibility with regard to class assignments and deadlines to help alleviate student stress. This was much appreciated by the students.

> "*One of my [professors said] … 'If you feel like you want to be participating in these protests and like there are things you could be doing with your time better than studying for this final... I'll just remove the final from your grade'... It was really nice that he was acknowledging what was going on."*

Some professors were highlighted for going the extra mile for their students. One professor planned a special end-of-quarter Zoom™ social gathering for her senior project students. Another professor implemented weekly check-ins, which sent a message to students that he cared about their wellbeing.

Students also appreciated opportunities to speak with professors one-on-one, especially if they wanted to discuss personal or sensitive topics. They appreciated when faculty created space for private discussions. For example, one professor offered eight individual 15-minute meetings per week that students could sign up for via Calendly™.

Recommendations for faculty are as follows:

- Although we've become somewhat accustomed to virtual learning, mask-wearing, and social distancing, the fall quarter still has the potential to be disruptive to students. Covid-19 cases still on the rise, and many are apprehensive about November's Presidential election. Consider proactively addressing students' concerns through the form of check-ins (Canvas survey, a free response question tacked on to a homework assignment, etc.).
- Proactively check-in with students who are not participating in class or are falling behind
- Consider communicating and implementing some degree of flexibility with regard to course deliverables.
- Provide opportunities for one-on-one meetings with tools like Calendly ™, which seamlessly integrates with Zoom™.

- Avoid email-only office hours or discussion-board only office hours, as students found these to negatively influence their relationships with faculty.

Student Motivation

During the virtual quarter, student motivation levels varied from student to student. Some of the most salient factors influencing motivation were the lack of social connection, personal habits and environment, and the perceived level of support from professors.

With few study groups or opportunities to collaborate, students' lack of connection with their peers hindered their motivation. They struggled with a lack of "positive peer pressure", as their desire to put forth effort and to succeed was normally reinforced by seeing their peers do the same. Many students mentioned how class sessions where the majority of cameras were left off decreased this positive peer pressure and their sense of accountability to participate and pay attention during class.

> *"I felt like I was like a prisoner in solitary confinement, and my only way to be myself was through work, which wasn't really entertaining. I just felt the total loss of any social contact with other students and [it] really just destroyed my motivation for most of these classes."*

Students' personal habits and environment also influenced motivation. For example, waking up right before lectures and joining Zoom™ in their pajamas hindered them from performing their best. Because of this they were also less likely to turn on their cameras, since they did not want to look unpresentable in front of their professors and peers.

> *"I had a little less motivation because I would get out of bed and kind of stumble into class, instead of getting ready and actually going to class. Being at home too, I feel like it was…. you weren't as motivated, and I feel like that kind of like played into maybe doing less homework or not putting as much effort into the homework."*

The influence of being at home vs. being on campus also influenced motivation. Some students enjoyed having more time with family yet felt that being at home in an informal environment made it difficult to stay focused. This was especially true for students who depend on frequent changes of scenery throughout the day to stay energized and keep focused. Some students struggled without a designated workspace and dealt with frequent distractions from family members.

> *"I tend to be the kind of person that associates different physical locations with doing different tasks. It was a strange experience doing everything in one place, and I think that definitely affected my motivation."*

Professors in general seemed to have an influence on student motivation. Professors who "felt good about what they were teaching" caused students to "feel good about what they were learning." Students noticed and appreciated professors who demonstrated efforts to "go the extra mile." Some examples mentioned were professors who engaged students in interactive office

hours, set up and participated in extra study sessions, and carved out time during class to "make jokes" or talk about "non-class" topics.

The theme of motivation was something we found to be very important we decided to create a table summarizing the results.

Table 1. Topics in response to focus group question about motivation levels

What were your motivation levels like this quarter? What influenced your motivation?

Theme	Positive Experiences	Points of Improvement
Home environment	Less distractions because they can't hang out with friends, and there's no need to travel between classes	Some students did not have designated study spaces at home
		Being at home with family made it harder to concentrate
Faculty influence	Students felt more motivated when it seemed that the professor was putting in more effort and cared	Provide more structured opportunities for students to connect with each other outside of class
Peer influence	Group text chats helped peers motivate each other	Lack of interaction and "positive peer pressure" decreased motivation
Class format	Synchronous classes were better for maintaining engagement and motivation	Consider integrating some degree of choice into the class structure by allowing students to choose which assignments or quizzes they complete out of a pool of assignments and quizzes
	More hands on/lab-based classes were better than turning them more into theory-based classes	Encourage students to have their cameras on during class
		Zoom fatigue- students get burnt out faster

Some papers we reviewed noted a negative parallel between the emergency online learning shift and student motivation levels that our research also reflected. As stated by Vielma and Brey [3], students who faced self-motivation issues typically were affected by one or more of the following:

- A home environment non-conducive to learning,
- "Lack of focus to view videos online, attend lectures, or spend the majority of their time on the computer,"
- as well as "lack of concentration, optimism, commitment, balance, and time management skills."

The lack of peer-to-peer interactions was also observed to affect student motivation and satisfaction with learning at other institutions [2, 4, 5].

Building Community

Building community and promoting social interaction is one of the most difficult things to recreate in a virtual environment. The desire to work in smaller groups was consistent across the focus groups; students lamented losing the time before and after class to chat with friends, set up study groups, and meet new people. Additionally, many classes offered in the spring didn't

include group work or projects, which made it particularly difficult for first year, second year, and transfer students, who knew fewer people from previous classes and struggled to build networks.

Breakout rooms on Zoom™ were popular among those interviewed. Most students said they preferred having the same groups for a longer duration of time (e.g., for the entire quarter) or said they preferred only changing groups once or twice. One student suggested having frequent "low-stakes" discussion questions during lecture and doing 5-minute breakout rooms so students could discuss with one another. Another remarked:

> *"I became friends with [my lab-mates], but it wouldn't have happened if it weren't an assigned group. I think the fact that we stuck with that group for a long time also helped with it because we were able to get closer throughout the entire quarter."*

Having cameras on during Zoom™, particularly during these breakout rooms, was consistently mentioned as a way to help build community. Students provided a number of reasons for having their cameras off, including that they were still in pajamas for early morning class, embarrassed about their environment (e.g., garage, messy bedroom, living room, etc.), the fact that when other students have cameras off it feels awkward to have cameras on, unstable internet, and much more. The students recognized several benefits of having their cameras turned on, including increased focus, interaction, and engagement for everyone, as well as an increased sense of community. Lastly, students recognized the difficulty instructors face when speaking to a blank screen.

Several students mentioned that it was particularly difficult to meet friends and form groups in asynchronous classes, which is why assignments where students can interact with one another are imperative. Assignments such as discussion boards can be done over Canvas™, although some instructors used platforms such as Piazza™. Meanwhile, some students enjoyed using FlipGrid™, which allows them to record videos for class assignments or simply to introduce themselves asynchronously to their professor and to their peers. Students especially liked video assignments when faculty would take the time to respond authentically, building community despite the asynchronous setting.

Table 2. Topics in response to focus group question about building community

How have faculty tried to help you build community in your classes? What hindered community building?

Theme	Positive Experiences	Points of Improvement
Cameras on/off	Having cameras on increased sense of community	Classes where most cameras were off made it difficult to connect
Lab/project collaboration	Group projects were a good way to foster connections	Professors should pair students up for lab groups
Breakout rooms	Putting students into breakout rooms and even having them just check in with each other before getting classwork done helped foster community	Harder to communicate/socialize in breakout rooms with >4 students
Faculty-student interactions	Faculty with more frequent Zoom office hours engaged well with students	Email-only office hours made it difficult for students to interact with professor
Mode of instruction	Synchronous classes	Asynchronous classes did not allow for community building
	Canvas discussions were a good way to interact with peers asynchronously	Students want more interactive discussion-based classes
Student-driven interactions	Knowing peers from past classes made it easier to reach out	Professors should encourage students to form group chats, make roster available so they can set that up
		1st & 2nd year students struggled more with interacting with peers because they didn't know many of their peers

The concept of peer-to-peer communication also tied into the subject of *Building Community*, a concept we found to be integral to whether students felt comfortable and satisfied in their courses. Students regretted the loss of pre- and post-class time to relax with peers and socialize. Park et al. [2] suggests that coordinating time during online classes specifically geared toward encouraging students' mental and emotional health could improve overall student learning outcomes. One typically effective way to build community in online classes was to assign group projects. The students we interviewed mentioned there was a significant a lack of group projects in the first quarter post-transition, which put certain grade level students—namely, first-year and transfer students—at a disadvantage for building support systems. Nonetheless, when group projects *were* implemented, students interviewed said they struggled to communicate with other group members and stay on top of work. Vielma and Brey came to a similar conclusion, stating that "students found difficulties coordinating schedules, meeting online with group members, and collaborating with all members in the group" [3]. In order to build stable relationships with professors, some students suggested the creation of low-stakes assignments during synchronous classes that included more student-faculty interactions. Jamieson [5] came to a very similar conclusion, determining that authentic interactions with their professors greatly improved students' feelings of community in a class.

Technology & Access

Issues with technology as well as access to resources detracted from students' learning and professors' teaching. Many students and professors struggled with poor Wi-Fi connections. For this reason, students preferred when professors gave students the option to attend live lectures and when they would post the recordings for those who couldn't attend. Recordings also accommodated out-of-state students who lived in different time zones as well as students who learn best by reviewing lecture content.

Students also enjoyed virtual office hours and even went as far as requesting that professors continue to employ them when classes return in-person.

> *"I found that during virtual learning I'd be working on a project and then get stuck and then I'd be like, well, 'let's just go see when the nearest office hours are.' [...] They actually did a really good job covering everything so I can usually [...] hop on and get that answered, which ... I think that is really helpful."*

Quality of learning was particularly affected by the poor audio quality of some lab and lecture videos. Moreover, students found it difficult to read and follow along with handwritten notes. Besides sometimes illegible writing, handwritten notes were problematic because the professor's hand often blocked their writing. Despite this, some students appreciated it when professors wrote live notes, particularly when using a tablet.

With regard to submitting important assignments, students found the expectation to immediately upload exams after completion confusing. Uploading documents within a short time period was stressful and depended on what technology students had available, since not all students owned scanners or printers.

> *"One of my friends had to use his printer every time to upload the PDF [for exams...] I didn't know how he'd manage that within the time limit."*

Finally, students suggested that the best way to decrease technological issues was for professors to become familiar and comfortable with the software they use. Specifically, students recommended professors familiarize themselves more with screen sharing, breakout rooms, and poll features on Zoom™. Moreover, students appreciated professors who were able to effectively use Canvas™, both for communication as well as assignments. One noteworthy Canvas™ feature is the calendar function, which enables professors to share the timeline for course assignments with students.

The issue of using software went both ways; students also struggled with technology issues. They mentioned having to spend significant amounts of time working through these issues, which took away from the time they were able to devote to learning the class material.

> *"The workload shifted from coursework-focused workload to more of figuring out technical issues and various inefficiencies introduced by [...] software."*

Students appreciated flexibility from their professors and found it very helpful when both parties had proper expectations of one another.

> *"Students who are actually taking [online classes prefer] flexibility in general and understanding that there are going to be technical issues, there are going to be all these things that come up that we can't avoid because we're not in person."*

Recommendations for faculty are as follows:

- Continue to develop skills using Zoom™ and Canvas™.
- A workaround to live/handwritten is to scan your handwritten notes or animate a slide with them on it.
- Consider using digital whiteboards, screensharing, and/or a tablet to replace handwritten notes.
- If students don't have access to printers/scanners, suggest the use of free phone apps that scan documents.
- For high-stakes assignments, give students a grace period to upload exams and do not make the uploading process/time part of the exam period.
- To prevent audio issues, consider requesting good microphones and/or headphones with built-in microphones.

Assessment & Academic Integrity

Maintaining academic integrity and developing appropriate assessment methods were a point of contention during the virtual quarter. When it came to the various methods of student assessment, some students preferred open-note exams because it reduced students' desire to cheat. Taking exams open-note and working with other students over a 24-hour period also gave students the chance to also use assessments as a learning opportunity and to reinforce their knowledge.

> *"... being able to spend a lot of time on [open note] midterms and getting almost like a 100% on them because I put in the time and effort to learn and work... I think the experience is just a lot different. [...It's like] 'I took my time using my resources and was able to come up with something I felt good about and actually did do good on.'"*

Meanwhile, some students preferred when instructors replaced exams completely with term projects. This method also mitigated cheating, and allowed students to learn from their project experience and interact with other students. Students argued that projects were a good replacement for exams because they were able to demonstrate their understanding and learning of the material in a more authentic way.

> *"[In my controls class] the professors actually eliminated all exams from the class and instead they had a quarter long term project where there was a real-world system that we analyzed and made a model of over the course of the quarter. Basically, [we were] applying what we learned each week in class to that system, and I actually really enjoyed that."*

Another assessment technique that professors employed was proctoring through Zoom™ and requiring students to turn their cameras on; students had mixed feelings about this. While it managed to deter students from cheating, this also tended to increase student stress levels. Additionally, students noted that their peers would go to whatever lengths they felt necessary if they wanted to cheat; including having notes off to the side, using their cell phones, or even employing a second monitor. Therefore, they felt like requiring cameras on was not always helpful. One thing that students did find useful during these types of exams was being able to ask professors questions (via the Zoom™ chat feature) as if they were in person.

A handful of students said they took classes where microphones were required to be turned on during exams. Although they understood the benefits, students agreed that requiring microphones to be on ended up being more disruptive than helpful. Pencil tapping, whispering, and noises from students' environments proved especially distracting.

Lastly, students disliked the "backtracking" and "lockdown browser" features of Canvas, and preferred short answer questions to multiple choice ones.

> *"I know a lot of professors [...] got rid of the backtracking feature [on Canvas quizzes], and that'll stop you from cheating, but in a real-life test you can go back to another question on your test... [If a student doesn't] know a question [they] have to give up on it and move on. It makes you lose a point where you know maybe later you get a brain spark or something so I didn't like that."*

Additionally, concerns surrounding assessments and evaluations were present in ours and other institutions' studies. As mentioned in our *Assessment & Academic Integrity* section, with online learning comes the risk of academic dishonesty, and students from our study understood this as they preferred assessment methods such as replacing exams with projects, take home exams, or open-note exams, similar to students from other institutions [4], [5]. Students in our focus groups also tended to dislike using lockdown browsers or programs as they prevented them from reaching out to their professors for questions or posed serious problems when their internet went down. However, a study from another university navigated around this issue by using a lockdown program that still saved student work and allowed them to continue the exam if their internet went down [5].

Table 3. Topics in response to focus group question about academic integrity

What are some ways you think we can protect academic integrity?

Theme	Positive Experiences	Points of Improvement
Assessment types	Open-note exams reduced student desire to cheat	Students liked it better if professors provided short answer questions over multiple choice since it is harder to cheat with short answer
	Students like taking an exam/assessment over a 24-hour period	Do not re-use questions on exams-- rewriting or making new ones helps prevent cheating as students could possible search for the questions on the internet
	Students like being able to take collaborative assessments	
Proctoring exams	Having cameras on was sometimes effective at preventing academic dishonesty	Cameras/mics on during an exam increased student anxiety
		Students preferred not using lockdown browsers or features on Canvas like preventing "backtracking"
Projects vs exams	Some students like doing projects instead of exams because it mitigated cheating and allowed for a more engaging way to master material	

Recommendations for faculty are as follows:

- Make sure students are familiar with what constitutes academic dishonesty at your institution.
- Similar to having an email sent from the department head, craft an academic honesty contract as a class that all students sign together at the beginning of the course.
- A workaround for requiring audio to be on is recommending that students turn their volume down, so the sounds of others aren't distracting.
- If you choose to assign a quarter-long project instead of regular exams, consider having intermediate turn-ins and peer review.
- If employing timed tests on Canvas™, write different versions of questions (question banks) and/or use different numerical values.
- Weight and keep grades up to date on Canvas™ so students are aware of their current grade in the course.

Conclusion

Through this study, we have identified how emergency online learning has impacted engineering students during the COVID-19 pandemic. Overall reactions to the online shift were varied, and students faced many hardships they wouldn't deal with during a typical school year. With support from their professors, many students were able to transition online seamlessly and continue their academic progress as planned. Nonetheless, the pandemic introduced issues—technical and social—that some struggled to overcome. Through our study we were able to outline some measures faculty may take to improve virtual engineering courses to benefit their students.

In addition to this study and existing literature, more research needs to be done to investigate the effects of this virtual switch further. One thing that is important to explore is how students from underrepresented backgrounds have been impacted. As many students from underrepresented backgrounds may face more road-bumps than their privileged peers, we find it important to explore what further struggles they may have faced. Moreover, it would be beneficial to study how long-term virtual education has affected engineering students, considering that many institutions are still delivering their curriculum either virtually or in a hybrid format. In the fall of 2021, for example, California Polytechnic University, San Luis Obispo will be employing myriad instruction formats, including fully online, combination/hybrid, as well as some fully in-person instruction. Our team is curious to see how the combination of hybrid and in-person instruction will affect the future generations of engineers. Finally, our own team's research can still be continued, as we can investigate faculty experiences through focus groups and use qualitative analysis software like Dedoose™, which would allow us to code focus group responses and identify different themes we might not have found before in interviewing students alone.

Continuing an engineering education and persisting through a global health crisis is a combined effort for all those involved, and we hope that this paper presents what has been working and what can be improved in order to successfully deliver engineering curriculum in a virtual format.

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