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Student Experience with COVID-19 and Online Learning: Impact of Faculty's Ability to Successfully Navigate Technological Platforms for Remote Instruction

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Student Experience with COVID-19 and Online Learning: Impact of Faculty's Ability to Successfully Navigate Technological Platforms for Remote Instruction

Introduction

This paper is based on a series of semi-structured, qualitative interviews that were conducted with students, by an undergraduate student and lead author of this paper, that focused on their experiences with educational technologies and online teaching pedagogy in the wake of the COVID-19 pandemic. As U.S. educators scrambled to adapt to online course delivery modes as a result of the first wave of the pandemic in the spring 2020 semester, those in the educational technology and online learning community saw the potential of this movement to vastly accelerate the implementation of online systems in higher education. A shift that may have taken 20 years to accomplish was implemented in two waves, first with the immediate forced shift to online learning in March 2020; and second, a less immediate shift to hybrid and online instruction designed to accommodate the different geographic variation in COVID-19 intensity, along with varied political and institutional ecologies surrounding online versus in-person instruction for the 2020-2021 academic year. With all of the rapid changes that were occurring during the spring of 2020, we wanted to investigate how students experienced and perceived faculty use of technology during this particular moment in time.

This study documents this transition through the eyes of undergraduate students, and demonstrates the varied ways in which faculty navigated the transition to online learning. According to our interviewees, some faculty were thoughtful and competent and provided a supportive environment that paid attention to a students' capacity for online learning, rather than maintaining traditional instructional practices. Others relied on practices from in-person instruction that were familiar, but appeared to be nervous in the new online teaching environment. Then there were those who seemed occupied by other concerns, where a focus on effective undergraduate teaching remained limited to begin with, and their approach to online instruction was driven by convenience. Our qualitative data clearly reveals that the ways in which faculty conducted their online courses directly impacted student learning experiences. In this study, we set out to document both the faculty instructional strategies in a hybrid/online environment and student accounts of those choices and their resulting experiences. While we continue to analyze this unique data set on this moment of transition in engineering education, we hope that this paper will also lead to policy recommendations regarding faculty adaptations to online instruction in general. We include some initial thoughts and recommendations below.

Background

I have chosen to switch between first-person and third-person narratives in speaking about my entry into this research since I am in the role of both a researcher and participant in the shift to

online learning. At the time of the forced shift to online learning, I was a junior undergraduate mechanical engineering major who had just discovered the field of Science and Technology Studies (STS). Throughout the fall 2019 semester, I began to question the ways in which I had been recruited and channeled, as a woman with an interest in science and math, into studying engineering. Upon taking an introductory STS course, I was introduced to reflecting critically about engineering as a field of study. This led me to enroll in a graduate seminar, Engineering Studies, which provided me with a much deeper introduction to STS-inflected studies of engineering, including engineering education. During this time, my professor, along with a postdoctoral fellow, were co-PIs for a study of student experiences in engineering education and had already convened a group of undergraduate students who were in the process of interviewing their peers. They were attempting to open the black box described in the National Academy of Engineering's *Pathways* (2018) study [1], which spoke of the different ways in which students experienced engineering education, and used their experiences as a stepping stone to a variety of careers, including many outside of engineering.

Undergraduate engineering education has almost always attempted to provide a professional degree, or at least the foundations of a professional degree, in just four years. This, along with the US commitment to providing a strong general education component at the undergraduate level, has made it difficult to unpack how students navigate challenging curricula and provides an important context for changes in engineering education. This earlier study was set up with a focus on diverse students and diverse student experiences, which provided a valuable entry into how different students experienced engineering education through their encounters with both their peers and faculty. These encounters, both good and bad, shaped what choices they made about their education; whether or not to stay in engineering; and if they left, what other major to choose based on the investments they made in their coursework so far. We discovered other things through this project, such as the importance of peer support groups; how peers contributed to learning; and how students learned to navigate challenges by choosing the right instructors, courses, and majors. In general, the project documented what student experiences were like in an engineering program. The fact that undergraduate students were interviewing other students also provided a rather novel entry into these experiences, since all of us were, in effect, acting in the role of consultative peers during the interviews we used to gather this data. We have written elsewhere about how this project constitutes a kind of methodological innovation into documenting student experiences, especially with regards to questions of ethnographic access.

When the pandemic occurred, we had an opportunity to transpose this experience into a study of how the same students experienced engineering education as a result of the sudden shift to online learning. At the time, the PI had a subaward for a separate NSF EAGER project focusing on the impact of educational technologies on the future of engineering education. All of us recognized very quickly that the sudden shift to online learning resulting from COVID-19 represented a seismic event in the engineering education ecosystem. In a context in which higher education already faced, and contemplated greater competition from online models such as massively open

online courses (MOOCs) and small private online courses (SPOCs) [2], the pandemic necessitated brick-and-mortar institutions to rapidly adapt to new online methods for education delivery. As such, I was brought onto the current project, along with two of my co-authors, to begin documenting educational technologies in the new environment of online and hybrid learning. They helped me to reformulate the research experience I had from the student perspectives paper into an interview-based study of student experiences with the online transition. The data and findings that I report on in this paper draw from that study and focus on questions of faculty engagement with educational technologies, as viewed from the eyes of undergraduate engineering students.

Literature Review

This study builds on a metaphor of engineering education as a complex ecosystem, a framework that is beginning to gain traction in the discipline. In contrast to pipeline models, which best simulate workforce supply and demand, and pathways models which we ourselves drew on earlier and describe how engineers navigate within the discipline, an ecosystem model captures the broad spectrum of mobilities, relationships and interdependencies that exist within and outside of the expected engineering career path [3], [4], [5]. Using ecosystem metaphors enables us to ask questions about the quality of pathways, the availability and flow of resources, and the structures and processes that create and sustain inequalities. Observing that systems are designed to reproduce themselves, Vanasupa and Schlemer argue that "the apparent problems of lack of learning and lack of diversity are outcomes of a system functioning as designed rather than something 'going wrong'" [6, pp. 6]. Observable leakage, which is often a primary driver in a pipeline metaphor due to projected inefficiencies, is merely the "tip of the iceberg," in a systems framework, beneath which a "hidden domain" consisting of social interactions, institutional structures, and cultural values are submerged [6]. In this project, we unwittingly became observers in the midst of an ecological crisis in higher education, in which students reeled from the loss of many of the "hidden" supports that they had come to rely upon. In particular, this crisis has highlighted the existence and importance of regular routines and social interactions--including peer support--that occur inside and outside the classroom for engineering students, without which they struggle to produce the sustained motivation needed to do well in their classes. Such supports are often taken for granted which in practical purposes can make them "invisible".

The research trajectory of this paper is supplemented by broad, diverse, and growing bodies of scholarship on undergraduate and graduate engineering student experiences in online education. This review of the literature encompasses studies conducted prior to the initial impacts of COVID-19, as well as an emergent body of scholarship on student experiences with online learning during and after the initial impacts of the pandemic. The review began with a survey of papers presented at panels in the ASEE 2020 conference proceedings, as well as articles published in the *Journal of Engineering Education*, and previous scholarship cited within these

texts. This allowed us to focus on literature that has been produced in engineering education research in particular, as well as scholarship that has gained traction within the field.

For instance, Shaoib's [7] review of the literature on student experiences in MOOCs reveals three principle concerns in online-only learning models: (1) accommodating multiple student learning styles, (2) facilitating student engagement online, and (3) reproducing similar or improved student outcomes online as in-person. Regarding student learning styles, researchers endeavored to characterize typologies of students in order to improve student experiences. Some studies emphasized participation patterns of students online, such as active learners, passive learners, and bystanders [8], or distinguishing "browsers" from "committed learners" [9]. Other studies emphasized the variety of learning styles such as "sequential", "visual", "verbal" or "active-reflective" learners [10].

Facilitating student engagement online is difficult in online-only environments, with a high percentage of MOOC participants tending to drop off in participation over the course of the module [11]. Studies indicate this is due to a combination of content delivery methods [11], [12] and student motivation [13], [14]. Participation in classes with hands-on components, such as labs and design classes, are also a significant challenge in engineering disciplines [12], [15]. To offset motivational difficulties, authors recommend that instructors shorten the length of their lectures to increase student attentiveness [11], and use a variety of techniques to sustain students' interest in the subject matter [13].

Despite faculty perceptions that online learning is not as effective as in-person [16], one meta-analysis of 45 empirical studies discovered that students performed marginally better in online courses than in person [17]. Blended learning environments appear to have the best learning outcomes, in comparison to both online-only and in-person settings [17]. These findings were corroborated by Ni [18] and Irvine et al. [19], who argue that the provision of extra materials in blended classrooms facilitates multiple student learning styles. Blended learning environments are also suggested for helping to bridge rural-urban educational disparities, facilitating learning either online or in person, according to the modes that are most accessible and feasible for students' lives [19], [20]. Indeed, these blended learning environments may be the key to increasing accessibility for low-income and minority students in higher ed, allowing students the option to participate virtually to accommodate part-time and full-time work schedules, or in-person for those who have difficulty accessing broadband services.

Student perspectives are considered in several studies [12], [21], [22]. Although faculty and students agree that communication is a common barrier in online settings [12], Dennen [22] finds that while professors are principally concerned with how well they are communicating content and expectations, students are most concerned with how their professors are communicating with them as individuals; the isolation of online environments creates conditions under which students want to ensure that they feel seen and cared for as learners [22]. To our knowledge, none of these

studies were conducted by an undergraduate student, which gives this study a unique perspective. Given the findings that students' experiences of the course may not track with professors', the presence of an undergraduate interviewer helps us gain deeper insights into the experiences of engineering students.

Most of the research we surveyed was conducted prior to the COVID-19 pandemic, and as such, took place during a time when external social and structural supports were still in place. The sudden mid-semester closures of campuses and directives to move courses entirely online created chaos in the higher education ecosystem and collapsed many of the support structures students had taken for granted, such as campus communities, study groups, and regular routines. As a result, this research project conducted during the initial months of the pandemic reflects not merely the challenges of working online, but rather working online under social isolation.

Methods

Our study was based on utilizing semi-structured interviews from a broad spectrum of subjects. The interviews I conducted were part of a paired study design: a postdoctoral fellow to the project, later joined by a graduate research assistant to the project, interviewed engineering educators, ed tech executives, and industrial HR managers and educators who hired engineering graduates regarding their attitudes towards educational technologies as well as how their view and uses of these technologies changed as a result of the COVID-19 pandemic. My focus was on collecting student experiences of the forced online transition, where a significant portion of the interview protocol asked about how faculty adjusted to the new instructional environment, and how they utilized educational technologies such as Zoom and WebEx, and supplementary platforms such as Discord, Slack, Chegg, and social media.

For my portion of the study, I interviewed 22 students between June 24-August 18, 2020. Subject selection was based on a matrix that prioritized diversity of subject, versus representation relative to the population as a whole, and was based on attaining relatively balanced numerical representation across the categories depicted in Table 1.

Table 1 - Selection Matrix

		Public university	Private university	Public engineering school	Private engineering school	Liberal arts college
Race						
	Caucasian	x	x	x		x
	Black or African American			x	x	
	American Indian or Alaska Native					
	Asian	x	x		x	
	Native Hawaiian & Pacific Islander					
	Other	x			x	
Ethnicity						
	Hispanic, Latino, or Spanish origin	x		x	x	
	Non-hispanic, Latino, or Spanish origin	x	x	x	x	x
Gender						
	Man	x		x	x	x
	Woman	x	x	x	x	
	Non-binary					
Socioeconomic Status						
	Lower class	x				
	Middle Class	x	x			x
	Upper Class	x				
Geographic Location						
	East Coast	x	x		x	x
	South	x	x	x		
	West	x		x		
	Midwest	x	x			

After collection, the data was subsequently coded in NVivo. We utilized “in vivo” inductive coding methods, common in grounded theory studies [23], [24], [25], , in which we searched for patterns and generated codes based on the topics that students felt strongly about. This paper specifically focuses on students’ comments about faculty engagement with educational technologies during the pandemic, their associated pedagogic choices, and students’ experiences and opinions of them. Some example “in vivo” codes that pertain to the changes that students experienced are as follows: “I had to find things to motivate me and find things just to occupy my mind”, “no longer having that ability to collaborate was just very difficult”, and “if they wanted reduced tuition, that means they don’t think learning is the same”. From these initial codes, we sorted them into patterns, which included topics such as “changes that students needed to make to complete class work”, “perceived effectiveness of professors”, and “university plans for fall 2020”. This bottom-up coding technique allows the students’ voices to be the drivers of categories that emerge from coding, rather than the researcher imposing categories on the data. We used the diversity in positionality within higher education of our team to try to minimize confirmation bias since structured coding is subject to the researcher discovering patterns they were already looking for.

Experiences/Perceptions

Since this paper specifically focuses on the experiences of undergraduate students who were taking classes during the spring 2020 semester, the analysis of the data will feature direct quotes from the interviewees and reflexive commentary from the author. This semester was a period of chaos and upheaval as students tried to acclimate to the changing educational climate while simultaneously watching an international pandemic unfold before their eyes. It is important to note that these interviews may have a negative bias because they were conducted over the summer of 2020 and specifically asked about the first wave of the COVID-19 pandemic. Regardless, these comments reveal important fractures in the ad hoc online education system that was quickly stood up - particularly as pertains to motivation, time management, and social interaction - that will be important to consider in the design of online courses in the future.

Students Favor Active Learning Online

Whether it was through shorter synchronous lectures or 15-20-minute asynchronous lecture videos, professors who replaced lecture time in favor of more collaborative activities were able to continue to build the rapport between students and professors that is typically formed during in-person office hours. 18 of the 22 interviewees stated that they preferred synchronous learning in the online environment.

"A lot of my professors weren't as captivating and it's not like you're in class, you're on the computer and you just kind of have to sit there and watch them talk or watch them write and it's just not as engaging, so it was difficult to stay attentive. I know a lot of other students kind of felt the same way"
- Caleb[1], Senior[2], public engineering school, south

Frustration was a common word that was expressed in each interview. No one had chosen this method of learning and it was hard to simultaneously learn new material and learn how to learn in an online environment. Overall, it seemed that no one really enjoyed online learning, but some students were able to recall positive experiences in classes where professors were actively trying to make accommodations and engage everyone.

"When we were learning new material that made it extremely frustrating, even in person, but online. It just got worse because it was harder to kind of get [the professor's] attention."
- Christopher, Senior, public engineering school, west

The majority of the interviewees had classes that met synchronously and had some sort of lecture component. Long online lectures are hard to pay attention to, because there is no in-person relationship with the professor and students often become bored while watching someone on Zoom speak while just moving through slides. Subjects indicated that it was awkward to ask questions because video-conferencing software etiquette greatly differs from typical classroom etiquette. It was also hard for students to articulate their questions when they couldn't fully see what the professor was writing.

Yao is a senior engineering student at a large private university in the south majoring in mechanical engineering. She was taking 3 traditional engineering classes during the spring 2020 semester and described that it was a lot harder to focus on what the professors were saying during their Zoom lectures because they just weren't as captivating. In all of her classes, student participation decreased significantly and she fell into a cycle: falling behind on work, trying to catch up as soon as possible with her own resources, and then attempting to pay attention to her lectures again.

"I think everyone felt that it was much harder to focus when this [was] online. It's also more tiring; being forced to watch lectures on your screen for the whole day and it's easier to fall behind. Especially since a lot of lectures were also recorded you knew that you didn't really need to be at the lecture if you didn't want to. So, you could just say that 'I'll watch this later.'"
- Yao, Senior, private university, south

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[1] Students are identified according to their responses to confidentiality preferences in our IRB protocol. Students who have requested their interviews remain confidential have been given pseudonyms. Others preferred to be identified using their real names.

[2] Student's class year is based on their academic standing for the 2020-2021 school year. Students who graduated in the spring of 2020 are labeled as graduates.

Yao's experience is common among all students - many of us seemed to become caught in the cycle of falling behind on work because we found it challenging to watch boring Zoom videos for each class. The inconsistent schedule of learning was a cause for much anxiety in students, who reported that it led to a decrease in information retention.

Even though our data indicated frustration was rampant throughout the semester, some students appreciated how cohesive the shorter lectures were and even preferred them to longer, in-person lectures. Jacob is a senior at SUNY Binghamton studying mechanical engineering and was frustrated with his curriculum before the forced shift to online learning. He found that his regular lectures were quite repetitive and didn't think that they were a good teaching method at all. Once online courses were implemented, he appreciated how some professors significantly reduced their lecture time by recording shorter 15-20-minute videos and hosting office hours and problem-solving sessions during the regularly scheduled class periods. He felt like the shorter lectures made learning easier because they were distilled down into what he considered the "essential information". Shorter lecture videos could be watched whenever students wanted and the information was easier to digest.

"[When I have] lectures that are actually pre-recorded and downloaded on the computer, I can go watch them and then, when I space out and pause the video, I can go back and pick up on what I might have missed out on. So, the actual act of having recorded videos is really helpful."
- Jacob, Senior, Binghamton University

Professors implemented a wide variety of class structures, but in interviews students indicated they were happier with the courses that utilized collaboration and interaction aspects. Timothy was a senior at Western Kentucky University and faced a wide variety of course delivery methods after his school was shifted to online learning. One of his engineering professors decided to cut down lecture time by only lecturing for one of the allotted course time blocks per week and facilitating a group problem-sets during the remaining time blocks. Timothy admits that it wasn't the same as an in-person meeting but appreciated that his professor was making an effort to stay engaged with the students and keep information retention high.

"So originally, we have a Tuesday/Thursday class, and I go on Tuesday and Thursday, but the way that it worked for this one is: we have the lecture, it was still pretty long, an hour and a half and he rambles and he knows he rambles, so he only did a lecture for that one day and then we'd have a great assignment every Thursday that we have to complete."
- Timothy, Graduate, Western Kentucky University

Even during in-person learning, students reported they generally had a harder time connecting with the professors if their teaching style utilized longer lectures. Professors who went out of their way to facilitate class interaction, learn how to use educational technologies, and collect feedback from students elicited positive perceptions. Professors who understood and acknowledged the limitations of technology had a better chance of encouraging students to

continue participating and learning. Utilizing a mixed-method approach to teaching via Zoom and WebEx, professors were able to keep the audience's attention and students felt as if they continued to be in control of their education.

"The most challenging part was being in class and really paying attention to classes because a lot of my professors weren't as captivating. And it's not like you're in class, you're on the computer and you just kind of have to sit there and watch them talk or watch them write and it's just not as engaging, so it was difficult to stay attentive"
- Bridgette, Senior, Private engineering school, northeast

Asynchronous Learning Difficulties

Every student that was interviewed had some sort of asynchronous aspect to their classes once they shifted online, which proved challenging for many. Aside from flipped classroom scenarios, engineering classes are generally reserved for lecturing, example problems, and question/answer sessions, while homework and projects are worked on outside of class. Compared to synchronous activities, the asynchronous model is easier to implement because it doesn't require as much effort and planning. Because the transition to online learning was so sudden, it makes sense that professors looked toward implementing an asynchronous model, but students really struggled with this course design. Only 4 of the 22 interviewees stated that they preferred asynchronous learning in the online environment.

Tara is a graduate from Ohio State University who majored in food, agricultural, & biological engineering. She was taking six classes during the spring 2020 semester, two of which were engineering classes that both shifted to complete asynchronous delivery methods. She constantly felt like she was behind in her courses and she described how completing the coursework became more important than actually learning the material. She described how her university had put out guidelines for online course delivery, specifically mentioning that putting up a set of lecture slides with a voiceover was not allowed and any professor who used this method needed to reorganize their class. Tara utilized the feedback system that the university put in place to combat bad learning experiences, but her classes were never changed.

"I had one professor give us more textbook readings and I had another professor just post PowerPoints which is the opposite of what the policy was, but whatever." - Tara, Graduate, Ohio State University

Professors who relied heavily on voiceovers, lecture slides, and videos had considerably more difficulty keeping students engaged in their learning. Students reported that they felt as if they were suddenly doing more work than before because their professors weren't actively teaching the content. Even if a lecture video or slide deck is the same content that would be delivered during a typical class period, students reported that it felt as if the teaching responsibility had been unknowingly shifted onto students. Students tend to keep a stringent schedule during the school year that revolves around their class time, but not having mandatory class periods proved

tricky to navigate. It's easier to procrastinate when there is no routine or schedule that helps to hold you accountable for completing your work.

"The motivation really just got sucked out of the room. I don't know if I could tell you why, but it was a lot harder for us to sit in front of a computer around the kitchen table than to go to school."
- Christopher, Senior, public engineering school, West

Students had stronger negative feelings toward professors who didn't have a synchronous component, because they felt as if their professors didn't care about their education. Jessica is a 5th year dual majoring in biomedical and chemical engineering at an east coast private university. Some of her professors were close to retirement and didn't seem to put the effort into their online modes of instruction that students needed. Jessica was stuck between a rock and a hard place because her professors weren't responding to feedback and the administration at her school didn't step in. Her classmates felt the same way and rallied to try and get her university to lower their tuition rates because they didn't think their education was worth the money.

"Classes wanted to go asynchronous and tried to upload videos, but they would forget what the uploading schedule was and it was like a whole nightmare where class time was actually just office hours and it was just not good."
- Jessica, 5th year, Private university, northeast

Interviews indicated that it quickly became obvious to students that professors were not trained in any of the technologies that the schools used for classes. However generally students were understanding about the fact that no one was happy with the situation at hand. Our data contained a small number of accounts where it seemed that professors did not have any intention of learning new teaching methods, which elicited negative reactions from students. Benny, a senior from Colorado School of Mines studying electrical engineering, described how he was both appreciative and frustrated with his professors' abilities to use technologies. He understood that professors were doing the best that they could, given the circumstances and the support from the administration.

"It's really annoying and hard to pay attention and people would always have their mics on eating food or something stupid and then the teachers, as per adults, don't know how to use technology...they couldn't figure out how to record stuff or share screens or mute people."
- Benny, Senior, Colorado School of Mines

I found that many students tended to lash out at the professors who weren't willing to change their teaching strategies. This was especially true of seniors who felt like they did not have any sort of closure in their collegiate experience; students in their final year often felt as if they missed the typical senior year celebration as they learned how to adapt to a new form of learning. A sophomore from a northeast private engineering school described a phenomenon that I labeled "social activation energy". In chemistry, activation energy is the amount of energy that must be

provided to a compound to result in a chemical reaction. Hannah used the phrase to explain why it was harder for students to complete their work. Without any external support from professors or peers, students need to motivate themselves which is tiresome when it seems as if there is no end in sight.

"All the normal interactions you're used to are gone and in order to replicate that you will have to set up Zoom meetings and that's a lot of activation energy."
- Hannah, Sophomore, Private university, northeast

Students Facilitating Community Beyond the Classroom

I drew from my own experiences as an engineering student undergoing a rapid transition to online learning, in which I learned that in order to "survive" your semester's workload you need to have some sort of support group to help you complete your homework and study for exams. The workload for each course is so high that it always seems that there is not enough time to do every assignment and study session on your own. This led to serious struggles last spring since I didn't know many people in my classes and my roommates, who made up a considerable amount of my support group, all moved away for the duration of the pandemic. There's something comforting and motivating about being around other people who are also working, and this constitutes another form of hidden support. Even in the student union or the library when I wasn't with a group, I felt more inclined to get my work done than I did when I was home. Drawing from these experiences the interview protocol asked about the presence or absence of community - all 22 interviewees stated that they participated in some sort of virtual, student-led community after the forced transition to online learning.

"I'm not interacting with my professors as much, I'm not able to ask as many questions, I'm not able to talk to other students as much as I would have if I had been in person, so it's been an adjustment to learn that stuff independently and to rely more on the internet and online resources." - Samantha, Junior, Public engineering school, west

Every student said that they struggled to focus and stay motivated to finish their semester, regardless of the course delivery mode. When probed with the question "why weren't you motivated?", interviewees stumbled through their answers, which was interpreted as subjects themselves not being aware of the source of the hidden supports they rely on. Some said that the quality of their education decreased, others said that the professors became flippant with their teaching, but the most common answer was that the structure of an engineer's day had been completely disrupted.

"And also, you just missed the whole aspect of being with people and like actually talking to your professor. So, it's just, it's so different that it makes me not want to focus, but also not want to be there."
- Benny, Senior, Colorado School of Mines

Kristophe is a senior at Worcester Polytechnic Institute studying civil engineering and sustainability. He described how he struggled to keep a routine throughout the online learning period, because there weren't any concrete events or classes happening at specific times. He spent a lot more time hanging out with his roommates and playing video games as schoolwork became harder to complete. Before the COVID-19 pandemic, clubs, Greek life, and other extracurriculars ensured that students were embedded in communities for the duration of their week. When you have to plan your schedule around your extracurriculars, it's harder to procrastinate and fall behind on your homework.

"There would be times where, you know, you'd be inside [for] maybe three days and be like, 'Yo, I haven't been outside in a couple days, that's kind of crazy.' You're doing the same routine over and over again. You kind of get lost in it, right. And you get really monotonous and sometimes [that] even makes you less productive."
- Kristophe, Senior, Worcester Polytechnic Institute

Many students made a significant effort to keep working with study groups and facilitate meetings throughout the spring semester. Groups of students would organize regular homework and study sessions on Zoom and learned how to use the features like screen share, annotations, polling, breakout rooms, and live transcriptions to complete their work. Others used collaborative applications like Slack and Discord. Discord started as a platform for video game players to voice chat and invite their friends to play co-op games, but has recently turned into a platform that can be used for any sort of collaboration. This was a useful way for students to transfer everything from coursework to clubs to a virtual setting.

"My chemical engineering class, we were super tight. There were 30 of us, so we would literally just reserve big rooms and it would be 15 to 20 of us sitting in a room together working on assignments, so that was really hard to do once we moved into virtual learning. Me and my two best friends, we would go on Zoom to work on homework together."
- Jessica, 5th year, Private university, northeast

When students had classes that weren't as conducive to an online environment, they banded together to form academic and social support groups. Annai is a sophomore at University of California, Berkeley studying chemical engineering and described how it was harder to stay organized in online classes, even with the weekly study groups she had with her friends. Going back to the concept of social activation energy, setting up study groups, learning new tools to explain concepts to peers, and meeting for group projects took a lot more effort compared to when school was in-person. Students relied on each other, now more than ever, to learn their class material and it was hard to find support and provide support as the pandemic raged on.

"I feel that overall, the whole learning experience was different, because before, I'd have study groups with my friends or pay more attention in class. But online really just mixed a lot of things. It was much harder to concentrate in class or to stay organized all around."
- Annai, Sophomore University of California, Berkeley

Many students used a combination of the educational technologies and personal technologies to have club meetings and hang out with their friends. Brigette is a senior from a northeast private engineering school studying aeronautical engineering. She described how the clubs she was involved in stayed active and used WebEx to continue general meetings and host public events. There was a general understanding amongst the students that everyone was struggling with the lack of routine, so they exercised control over the things they could to keep some sense of normalcy in their lives.

"[We used WebEx teams for my] boundary layers [course]. And then I was using it for one of my clubs also to like, keep in contact with each other through the summer."
- Bridgette, Senior, private engineering school, northeast

Conclusion and Suggestions for Future Research

Despite these limitations, an important question is how can we create a virtual classroom that promotes content retention and has a positive impact on student perceptions of the quality of their education? The students interviewed in this study report high dissatisfaction with the lack of structural supports that existed in their previous in-person classes. Although early advice for instructors advocated asynchronous course design, this study shows that students preferred courses with at least one synchronous component with some sort of required participation, likely since it maintained structure. It is possible that prior research on asynchronous courses did not take into account the collapse of the majority of students' social activity during the pandemic. The synchronous option helped to overcome the "activation energy" required of students by creating a stable routine; it also provided opportunities for personal attention, making students feel cared for. Granted, synchronous course designs will require exceptions for students who have extenuating circumstances, so instructors will need to be flexible with absences and deadlines. In addition, instructors should reduce lecture length to 10-15 minutes each to effectively manage student attention spans, yet avoid oversimplifying the curriculum - students want to learn, so simplifying course material leads to the conclusion that the quality of education has decreased.

Finally, professors should consider integrating collaborative educational technologies like Microsoft Teams, Slack, and Discord into the class to promote group work outside of class. Students are using these features anyway and they can be a great way to increase peer-to-peer communication in the class. Professors should go above and beyond to establish and encourage personal communications between students and teachers, whether via email, message board, or other channels. Facilitating group work during class meetings is vital to information retention

and helps to foster relationships between students and the professor, even though the class is online. Professors should also make an effort to be reliable and consistent throughout the class; they should post information in a timely manner, keep up with emails, and familiarize themselves with educational technologies prior to the start of the class. Professors who work in conjunction with students to create a collaborative learning environment will help increase the quality of learning.

By engaging in an ecosystem metaphor, we argue that without the invisible support structures from prior to the pandemic, such as going to a classroom, maintaining a regular routine, using on-campus resources, physically being around others, and interpersonal relationships, students have struggled to engage online. However, the quality of a student's education can drastically improve based on their professor's effort to create a supportive learning environment. Students respond more positively when there is a basic structure for an online course, when they have established routines, and when there are additional modes of communication to connect them with their professors and their classmates. By incorporating these elements into their course designs, professors can help students who are struggling and improve their ability to learn, despite the obstacles we are currently facing. The authors of this paper have also created a reading list and extended guide on best practices in online learning [26].

References

[1] Committee on Understanding the Engineering Education-Workforce Continuum, "Understanding the Educational and Career Pathways of Engineers," National Academy of Engineering, Washington, DC, 2018.

[2] R.A. Cheville, K. Madhavan, J. Heywood, and M.C. Richey, "The wisdom of winter is madness in May," *Journal of Engineering Education*, vol. 108, no. 2, pp. 156-160, 2019.

[3] R.A. Cheville, "Board # 22 : Ecosystems as Analogies for Engineering Education," in *ASEE Annual Conference & Exposition*, 2017.

[4] W. Lee, "Pipelines, pathways, and ecosystems: An argument for participation paradigms," *Journal of Engineering Education*, vol. 108, no. 1, pp. 8-12, 2019.

[5] S. Lord, M. Ohland, R.A. Layton, and M. Camacho, "Beyond pipeline and pathways: Ecosystem metrics," *Journal of Engineering Education*, vol. 108, no. 1, pp. 32-56, 2019.

[6] L. Vanasupa and L. Schlemer, “Transcending Industrial Era Paradigms: Exploring Together the Meaning of Academic Leadership for Diversity”, in *ASEE Annual Conference & Exposition*, 2016.

[7] H. Shoaib, "A Systematized Literature Review of Student Learning, Participation, and Engagement Experience in Engineering Massive Open Online Courses (MOOCs)," in *ASEE Annual Conference & Exposition*, 2020.

[8] S. Tseng, Y. Task, L. Yu, C. Chan and K.R. Lai, “Who will pass? Analyzing learner behaviors in MOOCs,” *Research and Practice in Technology Enhanced Learning,* vol. 11, no. 1, pp. 1-11, 2016.

[9] K. Koller, A. Ng, C. Do, and Z. Chen, “Retention and intention in massive open online courses,” *Educause Review*, vol. 28, no. 3, pp. 62-63, 2013.

[10] R. I. Chang and F. L. Chun, "Survey of learning experiences and influence of learning style preferences on user intentions regarding MOOCs," *British Journal of Educational Technology,* vol. 43, no. 3, pp. 528-541, 2015.

[11] B. J. Evans, R. B. Baker and T. S. Dee, "Persistence patterns in massive open online courses (MOOCs)," *Journal of Higher Education,* vol. 87, no. 2, pp. 206-242, 2016.

[12] L. Kinney, M. Liu and M. A. Thornton, "Faculty and Student Perceptions of Online Learning in Engineering Education," in *ASEE Annual Conference & Exposition*, San Antonio, 2012.

[13] P. G. Barba, G. E. Kennedy and M. D. Ainley, "The role of students' motivation and participation in predicting performance on a MOOC," *Journal of Computer Assisted Learning,* pp. 218-231, 2016.

[14] B. D. Jones, M. C. Paretti, S. F. Hein and T. W. Knott, "An analysis of motivation constructs with first- year engineering students: Relationships among expectancies, values, achievement, and career plans," *Journal of Engineering Education,* vol. 99, no. 4, pp. 319-336, 2013.

[15] S. Badjou and R. Dahmani, "Current status of online science and engineering education," *Journal of Engineering Education,* vol. 4, no. 1, 2013.

[16] E. I. Allen, J. Seaman, R. Poulin and T. T. Strout, "Online Report Card: Tracking Online Education in the United States," February 2016. [Online]. Available:

https://www.onlinelearningsurvey.com/reports/onlinereportcard.pdf. [Accessed January 2019].

[17] B. Means, Y. Toyama, R. Murphy, M. Bakia and C. Jones, Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies, US Department of Education, 2009.

[18] A.Y. Ni, "Comparing the effectiveness of classroom and online learning: Teaching research methods," *Journal of Public Affairs Education,* vol. 19, no. 2, pp. 199-215, 2013.

[19] V. Irvine, J. Code and L. Richards, "Realigning higher education for the 21st-century learner through multi access learning," *MERLOT Journal of Online Learning and Teaching,* vol. 9, no. 2, pp. 172-186, 2013.

[20] J. Yang, H. Yu and N. S. Chen, "Using blended synchronous classroom approach to promote learning performance in rural areas," *Computers and Education,* vol. 141, 2019.

[21] Y. J. Park and C. J. Bonk, "Synchronous learning experiences: Distance and residential learners' perspectives in a blended graduate course," *Journal of Interactive Online Learning,* vol. 6, no. 3, pp. 245-264, 2007.

[22] V. P. Dennen, A. A. Darabi and L. J. Smith, "Instructor-learner interaction in online courses: The relative perceived importance of particular instructor actions on performance and satisfaction," *Distance Education,* vol. 28, no. 1, pp. 65-79, 2007.

[23] S. Elo and H. Kyngas, "The qualitative content analysis process," *Journal of Advanced Nursing*, vol. 62, no. 1, pp. 107-115, 2008.

[24] H. Hsieh and S. Shannon, "Three Approaches to Qualitative Content Analysis," *Qualitative Health Research*, vol. 15, no. 9, pp. 1277-1288, 2005.

[25] J. Corbin and A. Strauss, "Grounded Theory Research: Procedures, Canons, and Evaluative Criteria," *Qualitative Sociology,* vol. 13, no. 1, 1990.

[26] A. Akera, M. Shuey, and T. De Pree, *Advice on Online & Hybrid Instruction*, Jun-2020. [Online]. Available: https://rpi.app.box.com/s/gtb9n3mkvsacbx6vc7qjindtxohp4xza. [Accessed: 19-Apr-2021].