Adapting to Alternative Learning: Insights from Engineering Graduate Students During the COVID-19 Pandemic

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Navigating the Shift to alternative Learning: Insights from Engineering Graduate Students Amid the COVID-19 Pandemic

Abstract:
The global pandemic caused by COVID-19 necessitated educational institutions to shift from in-person instruction to online settings. However, engineering programs, predominantly hands-on by nature, demand students to acquire real-world experience for learning. The pandemic significantly affected these educational environments, limiting collaboration, reducing access to instructors and institutional resources, and overall impeding hands-on learning. In addition, research has highlighted that the move to online instruction has impacted students' sense of belonging and as a result their intentions to persist. It is therefore crucial to examine the extent to which these disruptions impacted students, both inside and outside of the classroom. Although graduate students were not alone encountering disruption to their curriculum and coursework, they are more often engaged in research that depends on access to physical laboratories and specialized equipment.

This study therefore aims to answer the following research question: **How did engineering graduate students experience the transition to non-traditional/alternative learning during the COVID-19 pandemic?** To answer this question, we analyzed qualitative data collected using the SenseMaker platform in response to the prompt "Imagine you are talking to a friend or family member about the evolving COVID-19 crisis. Describe something you encountered as an engineering student." Participants' responses were analyzed using best practices in qualitative coding techniques following an inductive, open-coding scheme. Preliminary analyses detail findings related to students' adjusting to virtual instruction, consequences for academics and career aspirations, and coping mechanisms students used to confront the challenges they the onset of the pandemic. Initial findings suggest possible factors that may be attributed to the increase in reported mental health problems during the pandemic (e.g., increased isolation, unclear expectations, etc.) and begins to explore effective stress management strategies graduate students' employee.

The results from this work highlight areas for future research, including the need to examine the long-term impact of the pandemic engineering graduate students' academic and personal well-being as well as a need to examine supports that can be adapted specific to graduate students' needs. This is significant because this paper aims to influence the employability and educational quality of graduate students, both of which are essential for promoting equity, innovation, and progress in the field of engineering education. Fostering a stronger, more diverse engineering community and advancing society hinge on ensuring equitable access to resources and education.

Introduction:
The COVID-19 pandemic has precipitated a global educational crisis, compelling institutions to pivot rapidly from traditional classroom settings to online learning environments. According to UNESCO (Meinck et al., 2022), over 1.5 billion students worldwide were affected by school closures, highlighting the scale and severity of the disruption across educational sectors. This shift has been particularly problematic for engineering education, which relies heavily on hands-on, practical training that is difficult to replicate online (Rassudov & Korunets, 2020). Engineering graduate programs outside the United States, such as those in Russia and China, have faced significant challenges in maintaining the integrity of laboratory and design courses, essential for the cultivation of practical and innovative skills in the discipline (Zhang, 2024). These disruptions have

not only affected immediate learning outcomes but also pose long-term impacts on the professional readiness and future career trajectories of engineering graduate students. The study's focus on understanding these impacts is crucial for developing adaptive educational strategies that can sustain the quality of engineering education in face of such global disruptions.

Literature Review:

The global outbreak of COVID-19 has brought about significant changes in higher education worldwide, necessitating a shift from traditional face-to-face teaching to online formats. This unplanned transition posed unique hurdles, particularly for engineering students, who rely heavily on hands-on learning and access to specialized resources (Sukackė et al., 2022). Graduate engineering students often depend on educational experiences such as collaborative projects, working with human subjects, and specialized equipment (Sukackė et al., 2022). The abrupt move to virtual platforms disrupted these critical elements, significantly impacting both academic progress and practical training. The shift to online learning, unplanned due to the pandemic, created widespread challenges for faculty, staff, and students to adapt to the "new normal." Additionally, research by (Moran et al., 2023; Paul et al., 2023) highlighted equity and access issues in virtual settings, emphasizing the urgent need to address these concerns amidst such abrupt changes. The mental health impacts of the pandemic on graduate students have been significant. Isolation from peers and mentors, coupled with uncertainties surrounding academic progress and job prospects, increased stress, anxiety, and other mental health issues (Zaniyah et al., 2021).

Before the pandemic, research already shed light on the diverse challenges encountered by graduate engineering students. Among these were struggles to maintain a healthy work-life balance. (Golde & Dor, 2001) observed the inherent difficulties in managing academic, personal, and professional responsibilities. Moreover, the relentless pressure to produce research outputs, including publications and conference presentations, often led to heightened stress and burnout (Nerad & Miller, 1996). Financial constraints were another prevalent issue, as limited funding opportunities, high tuition costs, and the need to support themselves and their families created substantial burdens (Leshner & Scherer, 2018). Low-income engineering students often faced additional challenges, such as the lack of adequate learning spaces and necessary equipment to conduct research or complete assignments (Dewitt et al., 2024). Furthermore, the demanding nature of engineering programs contributed to mental health concerns, including anxiety, depression, and imposter syndrome (Evans et al., 2018). Research by Bork and Mondisa (2022) emphasized the importance of social support, student-advisor relationships, and the influence of cultural barriers for international students in navigating these challenges.

Diversity and inclusion within graduate engineering programs also presented challenges. The underrepresentation of women and minoritized students highlighted the need for greater efforts toward fostering inclusivity and representation (Chubin et al., 2005). These insights provided a comprehensive view of the pre-pandemic landscape of graduate engineering education, emphasizing persistent challenges. The COVID-19 pandemic further underscored and exacerbated existing inequities in higher education. For minoritized engineering students, systemic biases and insufficient support structures compounded challenges already shaped by intersections of racial, economic, and health disparities (Lewis et al., 2023; Lewis et al., 2023). Additionally, the pandemic heightened mental health challenges due to isolation, disrupted routines, and increased uncertainty (Bork &

Mondisa, 2022). Access to mental health care became increasingly difficult, emphasizing the urgent need for institutions to strengthen support systems during crises.

Understanding the varied experiences of graduate engineering students during the pandemic is critical for developing more equitable, resilient, and supportive educational frameworks. These insights can guide institutions in implementing policies that address immediate challenges while strengthening the broader educational environment for future disruptions. Furthermore, by comprehending these challenges, universities and policymakers can design tailored interventions to enhance student well-being and success. Lessons learned from the pandemic can inform strategies for resilience and preparedness in navigating similar crises in the future (UNESCO, n.d.).

Methodology:

The overall objective of this study was to explore the experiences of engineering students at the onset of the COVID-19 pandemic. Based on the data collected, this paper's guiding research question is, "How did engineering graduate students experience the transition to non-traditional/alternative learning during the COVID-19 pandemic?" Both undergraduate and graduate participants were recruited using the researchers' personal networks, social media platforms, and partnerships with organizations like NSBE. Participants were given autonomy over the accessibility of their stories, opting for one of three categories: 1) Everyone, 2) Researchers Only, and 3) No one. To investigate this research question, we analyzed survey responses collected using the SenseMaker platform, where students were prompted to reflect on their experiences as engineering students amidst the evolving COVID-19 crisis. Sensemaking is a research approach used to understand complex and ambiguous data such as narratives (Van der Merwe et al., 2019)

Between June and July 2020, a pool of 500 micro-narratives was amassed from underrepresented engineering students. Participants in this research were asked to respond to the following prompt: *"Imagine you are chatting with a friend or family member about the evolving COVID-19 crisis. Tell them about something you have experienced recently as an engineering student."* The SenseMaker tool uses mixed methods analysis to allow participants to use quantitative responses to reflect on their micro-narratives. The process of utilizing this data collection method consists of four steps: 1) Initiation; 2) Story Collection; 3) Sense-making; and 4) Response (Van der Merwe et al., 2019). The qualitative component of this method requires students to respond to an open-ended prompt.

Following their responses, students used five triads, three dyads, and 6 to 8 multiple choice questions to make sense of their previously provided micro-narratives. The design of this framework follows that of a similar study conducted at the University of Georgia. The use of triads and dyads gives students a method of visualizing how they are making sense of their narrative. Triads and dyads allow the student to move the dot on the triangle (triad) or slider (dyad) to fit their narrative best (Hensley et al., 2022). This data was recorded using coordinates and analyzed for trends.

Table 1: Triads and Dyads that participants will use to self-signify their own stories.

Theoretical Grounding	*Question*	*Triad*
Autonomy	My actions were motivated by...	Expectations of others, Self-Care, Necessity
Investment/ Discipline	What was valued in this story was...	Willingness to Experiment, Grit and Perseverance, Planning and Efficiency

Internal alignment/ Alignment with others	The experience I shared influenced my sense of...	Confidence, Purpose, Belonging
Openness/ Reflectiveness	Any decisions that were made in this story were influenced by...	Intuition, Self-Reflection, Feedback from others
Flexibility	Thinking about the future, this story encourages me to...	Embrace risk, be willing to adapt, Rely on familiar ways of working
Thriving (overarching concept) + Accountability (sub-feature)	This story was about...	Struggle – Progress
Collaboration/ Competition, Selfless/ Selfishness, Social contribution,	In this story I decided to prioritize...	Myself/my own self-care – Needs/expectations of others
Support, rate of change	In this story, change is happening...	Too Slowly – Too Quickly

Qualitative narratives integrated into this study are exclusively those shared by participants who granted public access. For this study, we only consider the responses from students who identified themselves as graduate students for the question "In Spring 2020, my year in school is." 55 responses from graduate students were included in this study for qualitative analysis. The study followed the SenseMaker framework, an online platform facilitating mixed methods data collection and analysis, through a structured process comprising four stages: 1) Initiation, 2) Story Collection, 3) Sense-making, and 4) Response. Building upon an existing signification framework rooted in the notion of thriving (Schreiner, 2013; Sochacka et al., 2020; Tobias, 2004; Van der Merwe et al., 2019) which was previously developed and applied in a comparable study at the University **Blinded**, this research employed a framework consisting of five triads, three dyads, and 6 to 8 multiple-choice questions, as detailed in Table 1.

In our implementation, we have adopted qualitative research procedures characterized by their inductive nature, emerging properties, and reliance on our collective experience during data collection and analysis. We adhere to an inductive logic, beginning our analysis from the ground up rather than being swayed by pre-existing theories or personal. Within our qualitative research framework, coding techniques assume a pivotal role in organizing, interpreting, and deriving meaning from our data. Our approach involves (Corbin & Strauss, 2014; John W. Creswell, 2013)

Particularly, inductive and open-coding schemes served as foundational methods in our implementation due to their flexibility and ability to generate insights directly from the data itself (Saldaña, 2013), p. 165). This approach facilitated a deeper understanding of the phenomena under investigation, allowing emergent themes and patterns to surface during our analysis process (Saldaña, 2013; p. 200). For our research, we systematically categorized and labelled codes into broader themes. Additionally, our use of coding added rigor and transparency to our qualitative research by thoroughly documenting procedures and decisions, thus enhancing the credibility and trustworthiness of our findings (Creswell, 2013; Saldaña, 2013).

Results:

The data provided offers a comprehensive overview of residency status, institutional types, experiences, and racial demographics. Out of 55 respondents, the majority (40) are domestic, with 14

international and 1 preferring not to answer. Predominantly White Institutions (PWIs) are the most common, with 41 respondents, followed by Historically Black Colleges and Universities (HBCUs) with 6, and other types with smaller counts. In terms of experiences, negative experiences are notable, with high impact affecting 8 and very high impact affecting 9 respondents. Conversely, extremely positive experiences are significant for 6 respondents with very high impact. Racial demographics show a substantial number of Black/African American domestic respondents (35), while international respondents include 11 Black/African Americans and 2 Asians. This data highlights diverse experiences and demographics, emphasizing the predominance of PWIs and the varied impacts on student experiences across different institutional types and racial backgrounds.

Theme 1: The Shift to Online Learning: Impact on Academics, Learning and Research

The findings from the shift to online learning, as reported by graduate students in engineering, unveil a host of challenges impacting their academic and research endeavors. The shift to virtual platforms has disrupted established timelines for degree completion, resulting in delays in progress due to restricted access to essential resources such as laboratory equipment. Students have expressed difficulties in attending labs, with research results being delayed due to supply chain issues. Conducting research in such settings has proven challenging, compounded by scheduling constraints imposed by COVID-19 restrictions. These factors have ultimately prolonged the research timeline, significantly impacting and delaying graduation schedules. This delay has heightened concerns about career progression and post-graduation opportunities among engineering students. Frustration mounts as students grapple with the inability to conduct hands-on research and experiments, hindering their ability to advance in their academic pursuits effectively. Additionally, certain participants expressed feelings of missing out on valuable experiences due to their inability to conduct research. This underscored concerns regarding the progress they had achieved and the knowledge they had gained. The inability to engage in these activities made it challenging to maintain momentum and retain what they had learned thus far, leading to frustration.

> ***Quote**: As a PhD student, I couldn't go into my lab to conduct experiments for 2 1/2 months because of the understandable stay at home order. Working from home is difficult for me and there is only so much writing and reading I can do that will contribute to my research and dissertation. I was hoping to finish in another year, but 'm not sure if and how my schedule has been affected. I am very grateful to be able to return to my lab under new rules and limited hours; however, I am still limited by equipment failure from idleness and the need to coordinate with the schedules of collaborators to perform tests. I am worried that I will have to stay longer in my program than I intended as a result of this.*

In addition, the utilization of online learning methods, including presentations, pre-recorded sessions, and Zoom lectures, presents a myriad of challenges for engineering graduate students. Virtual lectures and presentations are observed to be less captivating, leading to difficulties in maintaining attention and understanding compared to traditional in-person teaching methods. These mediums often lack the immediacy and autonomy for students to seek clarification during the learning process. While pre-recorded lectures offer the advantage of revisiting specific sections, they also add additional time to the learning process. The incorporation of pre-recorded lectures, while providing flexibility, introduces complexities such as increased time requirements and a diminished opportunity for real-time interaction with instructors, further complicating the learning journey.

> ***Quote**: As an engineering student, I have found it very difficult to focus on my studies during COVID-19. The reason is because I have a very hard time paying attention to the presentation or the speaker without*

becoming distracted very quickly. It also affects how fast I complete my work. I found it actually harder being home trying to complete my class work on time versus being in classroom and turning it in in a timely manner. Being home in any situation in my opinion is a slight distraction especially if you have a significant other or kids. You are not in that same space that you once had when you were at work, it's different and you have to adjust.

As students engage in their coursework remotely from home, they are also required to take exams under the same conditions, further complicating their academic journey. This situation presents notable challenges; taking exams from home exposes students to various distractions within their domestic environments, such as household noise and technological interruptions. These distractions can significantly impact concentration and focus, potentially affecting the quality of their exam performance.

> ***Quote**: ...During the Pandemic my greatest struggle was that we were still told to do an exam online instead of just giving us projects. Before every exam, I would do rewrite my notes, highlight what I believed would be important, and even do practice exams, however I still found myself struggling a little during this period of online learning. My biggest caveat with online exams is and always will be taking it in the comfort of your home. Not only are you more relaxed, which comes out as more of an excuse than an actual issue with the exam, however some people are living with family. Sometimes it slips their minds that you are in the middle of an exam, which is what happened to me and during the exam. I could just hear people in my background talking, distracting me from the exam, each time I had an exam. I felt my speed for the exam significantly drop because I was wondering why they were talking so loud and so much when I told them I have an exam. For the first time in 2-3 years, I didn't finish my exams because I couldn't get through everything, not because I couldn't remember anything. However, despite all of these hardships of having to take 4 exams and 3 projects during the online era ..*

Theme 2: Managing Expectations: Insights into Faculty and Program Demands.

Insights gleaned from graduate students in engineering shed light on the multifaceted challenges associated with managing expectations amidst the transition to non-traditional learning formats. As students navigate the shift to online platforms, they encounter various issues, including internet connectivity issues and the financial burden of acquiring necessary tools and resources, such as devices and reliable internet access, which were previously provided by campus facilities. Moreover, the transition brings forth heightened expectations from faculty members, resulting in increased workloads and the postponement of journal publications (which is expected from doctoral students) due to unforeseen delays.

> ***Quote**: I am a graduate student on assistantship. I am used to working from my office. When the virus became more pronounced and we had to shift to working from home, it was not easy for me to transition. One of the issues I had was the slow internet connection. I also discovered that my personal computer was slow.*

On the faculty side, there is a parallel process of adaptation as educators familiarize themselves with online teaching methodologies, a topic often discussed within academic circles. However, beyond the academic realm, students also grapple with the social disconnect brought about by the absence of face-to-face interactions, which traditionally facilitate easier learning and understanding. The inability to ask clarifying questions in person and the absence of motivation and study group dynamics further compound the challenges faced by graduate students in engineering during this period of transition. Additionally, the collaborative nature of their research endeavors becomes

increasingly challenging to sustain in a remote setting, as the spontaneity and ease of communication inherent in face-to-face interactions are compromised.

> ***Quote**: Learning via Zoom has been hard. One can easily stratify my classmates on the basis of wealth and access based on the background of their homes on Zoom. I'd hoped to use the zoom automated background to disguise the reality of my life at home but it turns out that my computer is not fancy enough to enable that feature. I often put my video off unless I'm called upon to state my opinion or give an answer. I feel very disconnected from my learning.*

Furthermore, faculty members may inadvertently exacerbate the workload burden on students, assuming that working from home equates to more available time. This misconception leads to increased expectations for productivity and more frequent check-ins, further intensifying the pressure on graduate students to balance academic responsibilities with the demands of remote work. Despite these challenges, graduate students in engineering demonstrate resilience as they adapt to the evolving demands of their programs, seeking to overcome obstacles and maintain academic progress amidst the uncertainties of the COVID-19 era.

> ***Quote**: As an engineering student, when the COVID-19 experience hit I experienced a huge workload gain. It was really overwhelming with classes and trying to keep up with research. I also notified that I begin to experience anxiety and depression. I went to the hospital from having heaviness in the chest and then doctors not knowing what was wrong with me deeming it as just an allergic reaction. However, in actuality, I found out I was having panic attacks.*

In addition to addressing the two primary themes, the graduate students shared insights into how skin color impacted their experiences throughout the pandemic. They emphasized the injustices related to racial disparities, which became more pronounced during this time. This not only disrupted their usual activities but also added extra stress to their and their families' lives, intensifying the daily challenges they encountered. These discussions revealed the intricate ways societal issues intertwine with personal and familial stress, especially during global crises that impact different aspects of life.

> ***Quote**: Something that I have experienced is feeling like I'm judged even more during Covid. Almost as if my Blackness is causing more stress to others. For example, I went to the grocery store and wore a mask like I'm supposed to. The worker wanted to check my id and she asked me to pull my mask down so she could verify I was the person on the id card. However, I noticed the person didn't do this to other people at the grocery store.*

Discussion:

Our study highlights critical challenges and adaptations faced by engineering students transitioning to online learning environments during the pandemic. It adds to the existing literature on the challenges of replicating hands-on, collaborative experiences in online engineering education, heightening graduate students' isolation and affecting their academic and career paths. Preliminary analyses indicate significant long-term effects on students' career preparedness and mental health, necessitating multifaceted institutional responses that include robust online educational frameworks, comprehensive mental health support, and integrity measures for online assessments. These findings underline the need for educational institutions to develop adaptable, inclusive, and supportive strategies to not only manage immediate disruptions but also enhance the resilience of the

educational system against future crises, ensuring the academic integrity and mental well-being of students remain prioritized.

In this study, we approached the data with an open mind, focusing solely on answering our research question regarding how engineering graduate students experienced the transition to alternative learning during the COVID-19 pandemic. However, for future work, we plan to build upon this analysis by re-examining the same dataset through the lens of the Thriving Framework. This approach will allow us to explore not just the challenges faced by students but also the factors that contributed to their resilience, persistence, and overall well-being in the face of disruption. By incorporating the Thriving Framework, we aim to provide a more nuanced understanding of how engineering graduate students navigated these unprecedented changes and identify key institutional and individual strategies that foster success in non-traditional learning environments. This extension will help bridge the gap in existing literature by shifting the focus beyond barriers ultimately informing future educational practices that better support engineering graduate students in times of crisis.

Limitations:

This study, while comprehensive, faces several limitations that require consideration. The rapid shift to online learning necessitated reliance on self-reported data from students, potentially introducing bias from individual experiences and perceptions. Additionally, the geographical scope of the studies, primarily outside the United States, may not fully capture the unique challenges encountered in various cultural or educational contexts, thus limiting the generalizability of findings. This study does not differentiate among various engineering disciplines, which may each react differently to online learning transitions due to specific curriculum needs and the requirement for hands-on training. The temporal scope of this research also poses limitations; as the pandemic progresses, continuously evolving educational strategies and technological interventions could impact these challenges, underscoring the need for longitudinal studies to assess long-term effects on engineering education. Moreover, our study does not delve into the significant impact of this transition on faculty, whose adaptation to online teaching is crucial for student success, nor does it analyze data on whether students are enrolled in thesis versus non-thesis master's programs or doctoral programs. This oversight limits our ability to generalize these findings. Our participant base, spread across the United States—where many students could stay close to family—does not represent international students, whose experiences remain unexplored in our dataset. Despite these limitations, we hope this research highlights issues that could help transform online education into a more inclusive system.

Conclusion:

In conclusion, this paper highlights the profound shifts and challenges faced by engineering students transitioning to online and alternative learning environments during an unprecedented global crisis. The study underscores the critical need for adaptive educational strategies that cater specifically to the hands-on, collaborative nature of engineering education. It calls for ongoing support and the development of robust online infrastructures that can sustain not only the academic rigor but also the mental and emotional well-being of students. This research serves as a crucial foundation for future policy-making and educational planning, ensuring that the resilience and adaptability of educational institutions are enhanced for any forthcoming challenges. By fostering an environment that is responsive to the needs of all students, particularly those from marginalized backgrounds, educational institutions can promote a more inclusive and equitable academic landscape. This approach will not only help mitigate the impacts of the COVID-19 pandemic but also strengthen

the educational system against future disruptions. Although this study highlights the challenges and needs of graduate engineering students, it also underscores the essential support required to nurture them. Many of these students are not traditional learners; they often juggle multiple responsibilities alongside their academic pursuits. Therefore, we argue that empathy and institutional support from faculty members must go hand in hand to facilitate their transition to alternative learning. By fostering a supportive and understanding environment, institutions can help students reach their full potential, ensuring their success in graduate school and beyond.

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