Examining Factors Related to Engineering Graduate Students' Mental Health Experiences

by

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Dedication

I dedicate this dissertation to the little girl who the second she heard that a PhD was the highest level of education she could get, she went for it, to the young adult who figured out how to make that dream possible, and to the woman who persevered through so much to get here. We did it.

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Abstract

Mental health impacts students on human, academic, and economic levels. A growing national mental health crisis over the past decade has left higher education institutions struggling to meet students' mental health needs. Understanding the scope and impact of these experiences for engineering graduate students is critical to supporting their academic success and reducing attrition. My thesis addresses the research question: "What are engineering graduate students' mental health experiences?" This dissertation includes three studies: a scoping literature review, a photovoice study, and a quantitative analysis study. This work found that engineering graduate students have a range of mental health experiences (i.e., positive, negative, and mixed), and that the culture of engineering corresponded mainly to students' negative mental health experiences. Findings suggest that to promote students' academic success, we must work to support students' positive mental health experiences and mitigate or remove negative ones. This requires a cultural change. Stakeholders at all levels (e.g., industry employers, national policy makers, faculty, students, etc.), must critically reflect on the norms, values, and assumptions we make, and work to intentionally align our actions with our intentions.

Chapter 1 Introduction[1]

1.1 Motivation

This dissertation will explore the mental health of engineering graduate students. The goal of this work is to help uncover the mental health experiences of engineering graduate students and how these experiences impact their experiences in graduate school. Mental health can impact anyone on a variety of levels (e.g., individual, communal, societal, etc.). A growing national mental health crisis underway for over a decade has left higher education institutions struggling to meet students' mental health needs (LeViness et al., 2017). A recent study of U.S. college students detailed a rise in student-reported suicidal ideation (5.8%–10.8%), mental health service utilization (18.7%–33.8%) and diagnosed mental health conditions (21.9%–35.5%) from 2007 to 2017 (Lipson, Lattie, et al., 2019). Graduate students have been shown to be more likely to have or develop a mental health problem compared to same age, highly-educated peers (Satinsky et al., 2021). Furthermore, engineering graduate students are less likely to seek help than their peers, which can severely impact the length and severity of their mental health problems (Lipson et al., 2016). Despite this, research on engineering graduate students has been overlooked.

The overarching research question guiding this dissertation is, *what are engineering graduate students' mental health experiences (within the United States)?* This research question will be answered through findings from this dissertation. Specifically, this dissertation will:

[1]Portions of the chapter are modified and adapted from [1]Bork, S. J. & Mondisa, J.-L. Engineering Graduate Students' Mental Health: A Scoping Literature Review. *Journal of Engineering Education*, 111(3), 665-702. https://doi.org/10.1002/jee.20465

(1) Provide an overview of the landscape of literature on engineering graduate students' mental health through August 2019. (Chapter 3)

(2) Provide an overview of findings from a photovoice study at a large, public, historically White institution that examines how engineering graduate students visually depict and describe their mental health experiences surrounding graduate school, and whether the culture of engineering had an impact on these mental health experiences. (Chapter 4)

(3) Quantitatively explore the relationship between the culture of engineering and engineering graduate students' mental health while accounting for students' gender, race, international student status, degree, and year in their program. (Chapter 5)

(4) Present a conclusion for this work and provide suggestions for future research directions to support engineering graduate students. (Chapter 6)

1.2 Intellectual Merit and Broader Impacts

This dissertation will first provide a synthesis of literature surrounding engineering graduate students' mental health, the culture of engineering, and the framework used to guide the study of the culture of engineering. This dissertation will the provide an understanding of the range of engineering graduate students' mental health experiences and detail factors relevant to understanding engineering graduate students' mental health experiences (i.e., academic, cultural, demographic, and relationship factors). Furthermore, this dissertation provides evidence for how the culture of engineering directly contributes to these experiences (mainly negatively). This work will help uncover engineering graduate student specific risk and protective factors. These factors can be used as the basis to develop an instrument to assess engineering graduate students' mental health. Furthermore, these factors can be used as the basis for targeted interventions that can be used to promote positive mental health experiences which in turn can support graduate students' success and retention.

1.3 Outline of this Dissertation

This dissertation presents a mixed methods research design to examine the factors relevant to understanding engineering graduate students' mental health and related experiences. My scoping literature review study details a need to expand research that examines the scope and impact of engineering graduate students' mental health experiences to support their academic success and reduce attrition. The photovoice study begins to address this need by exploring the range of mental health experiences of engineering graduate students at a historically White institution. Furthermore, by examining shared and differing mental health experiences related to the culture of engineering, this study details how the culture of engineering perpetuates harm through majorly negative mental health experiences. Finally, my third study expands on findings from the photovoice study by exploring a subset of themes of the culture of engineering quantitatively. This study supported the photovoice study, detailing a strong relationship between an increase in self-reported mental health problems and themes within the culture of engineering. Table 1-1 provides a more detailed overview for the studies included in this dissertation (i.e., Chapters 3 through 6), including the methods, findings, and implications for future work. In the rest of this chapter, I briefly summarize the intention for the following chapters in this dissertation.

Chapter 1 presents the motivation for this dissertation. This focuses on the problems I studied and why I have studied them. I also include an outline for the dissertation that includes the overall framing of the dissertation and how each study builds on one another.

Chapter 2 provides a review of literature central to this work, specifically, literature on

Table 1-1. An overview of the studies included in Chapters 3 through 5 in this dissertation.

Research Question(s)	Relevant Methods	Findings	Implications for Future Work
Chapter 3: Scoping Literature Review			
(1) What is the current landscape of literature about engineering graduate students' mental health?	***Data Collection:*** Searched articles up to August 2019 across five databases (EBSCO: CINAHL, EBSCO: PsycINFO, ProQuest: ERIC, PubMed, and Scopus). Database searches driven by pre-set inclusion criteria: Mental Health, Domestic Engineering Graduate Students, English Writing, Peer-Reviewed, No Date Range ***Data:*** n=4,826 possible studies ***Data Analysis:*** Sorted through possible studies using set inclusion/exclusion criteria that were enacted in the screening process; n=19 studies included in the review	(1) research on engineering graduate students is limited, and comparison between work being done is difficult as the motivations, methods, and foci of the work varies greatly (2) advising relationship & social supports are important potential protective or risk factors that can impact a students' mental health and academic experiences (3) there is a need to study more racialized, gendered, and intersecting nuanced experiences	(1) provide descriptive stats, and where able intersecting stats, on given demographics, mental health, and academic measures (2) include both positive and negative MH experiences (3) explore population level data for engineering graduate students' mental health (4) build on and expand work on international, Black, women, and Black women engineering graduate students (5) expand research on student-advisor relationship (6) extend research on social supports past the advising relationship (7) increase the number of intervention studies
Chapter 4: Leveraging Photovoice to Understand Engineering Graduate Students' Mental Health Experiences			
(1) How do engineering graduate students at a large, public, historically White university describe their mental health experiences, phrased as "emotional experiences"?	***Theoretical Framework:*** Bronfenbrenner's ecological systems theory (EST; 1979) ***Research Design:*** Convergent mixed methods design guided by photovoice methodology (emphasis on qualitative data) ***Data Collection:*** Pre- and Post-Surveys (n=8); Images and Captions (n=40); Individual (n=8) and Focus Group Interview (n=1) ***Data Analysis***: Thematic open coding to analyze images, captions -> used to provide codebook to semi-guide focus group interview transcript analysis and codebook; individual interview transcripts analyzed under focus group interview codebook to supplement / add context	(1) engineering graduate students have a range of positive, negative, and mixed (both positive and negative) mental health experiences during graduate school, and (2) engineering graduate students' mental health experiences cover six themes (i.e., activities, culture, identities, mental health and emotional experiences, quarantine life, support structures) that impact one another.	(1) expand research to include a range and mixture of mental health experiences (e.g., positive, negative, mixed, etc.) (2) expand mental health experiences to include major aspects of conflict and harm for individuals (e.g., discriminatory experiences) (3) work to reproduce and expand on these findings at other institutions; explore if these groupings of mental health experiences follow the six themes found in analysis (4) examine and develop interventions to promote positive mental health experiences and mitigate/minimize/remove the impact of negative experiences

Research Question(s)	Relevant Methods	Findings	Implications for Future Work
Chapter 4: Leveraging Photovoice to Examine Graduate Students' Mental Health Experiences within the Culture of Engineering (cont.)			
(2) How does the culture of engineering influence the mental health experiences of engineering graduate at a historically White institution (HWI)?	***Theoretical Frameworks:*** Godfrey & Parker's engineering education cultural framework (CEEF; 2010) as guiding theoretical framework and Bronfenbrenner's ecological systems theory (EST; 1979) as an analytical framework. ***Research Design:*** Subset of data from Chapter 4 (photovoice data, including survey data, captions, and individual interview transcripts) ***Data Collection:*** Pre- and Post-Surveys (n=8); Captions (n=40); Individual Interviews (n=) ***Data Analysis***: Construct participant profiles (using EST levels) to then perform cross-case comparative analysis (i.e., both within and between case analysis); leverage dimensions and themes in CEEF to guide analysis	(1) The culture of engineering does have an impact on engineering graduate students' mental health experiences, with most dimensions/themes of engineering culture relating to negative experiences. (2) Mental health experiences with the culture of engineering covered every dimension of their lives, from their individual backgrounds, experiences, and identities to transitional periods in participants' and their environments (e.g., transition to graduate school, COVID-19 pandemic, etc.) (3) Many experiences with the culture of engineering were shared; however, some differed based on a participants' background, identities, and/or previous experiences (e.g., educational background, race/ethnicity, nationality, gender, etc.).	(1) explore how to combat norms and assumptions from the culture of engineering, to reduce stigma on help-seeking, and align practices and policies to support positive mental health experiences across a diverse set of students (e.g., experiences, backgrounds, and identities, etc.) (2) explore how motivations, interests, and mental health experiences change throughout graduate school, and develop interventions that target needs at these different stages (3) foster connections between students to emphasize shared experiences past first impressions and/or initial biases/perceptions (4) explore and expand on trainings to recognize and learn how to combat personal biases, assumptions, and/or norms that can lead to discriminatory practices and/or behaviors (both overt and covert) (5) explore trainings to support both the student and the advisor in the student-advisor relationship (6) expand mental health research and support to faculty and staff in engineering
Chapter 5: Exploring the Relationship Between Engineering Culture and Graduate Students' Mental Health			
(1) How has the mental health of SEM graduate students, measured by depression, suicidal ideation, anxiety, and flourishing, changed over 2018-2021? (2) What role, if any, does the culture of engineering programs, have on engineering graduate students' self-reported mental health measures of depression, suicidal ideation, anxiety, and flourishing, when accounting for students' gender, race, international student status, degree, and year in program?	***Theoretical Frameworks:*** Godfrey & Parker's engineering education cultural framework (CEEF; 2010) ***Data Collection:*** Healthy Minds Network Healthy Minds Study (HMN-HMS) survey responses from 2018-2021. Focused on eleven measures of culture across two dimensions of CEEF and relationship to four proxies for mental health (anxiety, depression, flourishing, and suicidal ideation), and with five demographic controls (gender, race/ethnicity, international student status, degree, year in program) ***Data:*** n=3,564 responses from 2018-2021 from engineering graduate students (n=234 from 2018-19, n=1,857 from 2019-20, n=1,473 from 2020-21) ***Data Analysis:*** Descriptive (mean, standard deviation, min, max) and bi-variate (t-test difference in means, nested regression) statistical analyses	(1) self-reported mental health problems are on the rise (2) the culture of engineering programs is related to graduate students' self-reported mental health (3) specific measures should be explored (i.e., keeping feelings to oneself, sense of belonging, and degree persistence) (4) being an international, master's, and/or non-male (either female or neither female nor male) student all had higher scores for measures of mental health problems compared to White male domestic students in a doctoral program (5) the relationship between the culture of engineering graduate students' mental health and culture has unique elements compared to all graduate students (i.e., welcoming climate)	(1) expand on these findings to within the two dimensions of CEEF explored, as well as extend into the other four dimensions (e.g., relationships and relationship to environment dimensions) (2) explore additional quantitative data analysis methods for large data sets (3) establish norms to analyze mental health measures (4) conduct longitudinal studies to look for causal data analysis (5) expand research in qualitative and mixed methods research

engineering graduate students' mental health and the culture of engineering. It also provides an overview of the theoretical framework used to guide work examining the culture of engineering.

Chapter 3 details a scoping literature review conducted to explore the landscape of literature on engineering graduate students' mental health through August 2019. The findings of this review reveal that the research on engineering graduate students' mental health is limited and varies greatly. Although existing research literature was categorized into five main themes (e.g., cultural barriers internationals students confronted; gender and racial stereotypes; generalized findings; social support and sense of belonging; and the student-advisor relationship), comparisons across studies was difficult. Overall, this work details a need for future research to explore the mental health experiences of engineering graduate students.

Chapter 4 presents the findings of a photovoice elicitation study designed to examine (a) the range of mental health experiences of engineering graduate students and (b) the influence of the culture of engineering on graduate students' mental health experiences. This chapter first focuses on the shared mental health experiences across participants as discussed in the focus group interview. This chapter then presents findings from a cross-case comparison analysis examining the role, if any, of the culture of engineering on graduate students' mental health experiences. Findings detailed a range of mental health experiences, including positive, negative, and mixed (i.e., both positive and negative) that covered six themes (i.e., activities, culture, identities, mental health and emotional experiences, quarantine life, support structures). Furthermore, on average, the culture of engineering was found to impact students' mental health experiences negatively. Furthermore, although many of the experiences were shared, some differed based on a participants' background, identities, and/or previous experiences (e.g., educational background, race/ethnicity, nationality, gender, etc.). Future research can expand upon this work, examining the range of engineering graduate students' mental health experiences at other institutions and develop targeted interventions to promote positive experiences and remove/mitigate the impact of negative ones. In addition, future research focus on changing the culture of engineering, including reducing the stigma for help-seeking behaviors and aligning practices and policies within engineering (and higher education) to support positive mental health experiences for a student population (e.g., experiences, backgrounds, identities, etc.).

Chapter 5 explores the relationships between mental health, dimensions of the culture of engineering, and demographic factors using multi-year data. This quantitative study details how mental health measures (anxiety, depression, flourishing, and suicidal ideation) are useful proxies for exploring the relationship between culture and self-reported mental health. This study found a relationship between an increase in mental health problems and the culture of engineering. However, there were limitations in using previously created survey instruments in being able to explore these relationships (i.e., they are not capturing the nuance and scope of engineering graduate student experiences). Future work calls to extend these findings, primarily through the development of a survey instrument to specifically assess graduate students' mental health experiences.

Chapter 6 concludes this dissertation. I present a conclusion across the three studies in this dissertation, tying together the main findings and implications across these studies.

Chapter 2 Review of Literature[2]

This chapter begins by defining mental health for this dissertation. I then provide an overview of the two areas of literature relevant to this work: the mental health of engineering graduate students and the culture of engineering. Following this, I detail the guiding theoretical framework used to explore the role of the culture of engineering in graduate students' mental health experiences.

2.1 Defining Mental Health

This dissertation focuses on mental health, which I define as anything related to a person's emotional or psychological well-being (i.e., their mental and emotional state). The term "mental health" is often used alongside and/or interchangeably with a broader meaning of "well-being." Well-being has been more broadly defined as a "holistic concept referring to both physical and mental health … [including] personal safety and security, emotional support and connection, mechanisms to cope with stressors, and access to services" (National Academies of Science, Engineering, and Medicine [NASEM], 2021 p. 3). Although related, the scope for this dissertation is on mental health.

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[2]Portions of the chapter are modified and adapted from Bork, S. J. & Mondisa, J.-L. Engineering Graduate Students' Mental Health: A Scoping Literature Review. *Journal of Engineering Education*, 111(3), 665-702. https://doi.org/10.1002/jee.20465 and Bork, S.J., Young, N., & Mondisa, J.-L. (2022). Exploring the Relationship Between Culture and Science, Engineering, and Mathematics Graduate Students' Mental Health (Full Paper). *Proceedings of the Annual American Society of Engineering Education (ASEE) Conference*, July 26-29, 2022. Minneapolis, MN.

2.2 The Harm Caused by Pervasive Mental Health Problems

2.2.1 Human Impact

Mental health problems affect everyone on an individual, familial, community, and societal level. Death by suicide is and has been one of the top leading causes of death among college-aged students, second only to the rate of accidental injuries (J. C. Turner et al., 2013). In addition, self-reported mental health concerns have risen in the past decade, including the almost doubling of reported suicidal ideation (Lipson, Lattie, et al., 2019). A recent report on mental health, substance use, and well-being in higher education has highlighted concerns that the COVID-19 pandemic, the rise in unemployment and instability in the US economy, and increased awareness of anti-Blackness and racism has coincided with increased self-reported anxiety and depression (NASEM, 2021). This collective evidence calls for concerted efforts to address mental health.

Individuals with mental health problems (e.g., anxiety, depression, etc.) can have a lowered satisfaction with life and increased severity of mental health problems (Fergusson et al., 2015; Jenkins et al., 2020). Furthermore, individuals with two or more mental health problems are likely to experience greater quality of life impairment (Eisenberg, Golberstein, et al., 2009; Jenkins et al., 2020). This is concerning as mood, anxiety, and substance use disorders are highly comorbid among young adults, with roughly one-third of adults ages 18–29 meeting the criteria for two or more disorders (Tanner, 2015). Mental health disorders also coincide within families. Having a family member with a mental health illness increases the risk of mental health problems, and caregivers for people with mental health disorders suffer particularly significant mental and physical impacts (i.e., financial costs, social exclusion, isolation, stress, poor health; Ennis & Bunting, 2013).

Students with mental health problems are often concerned with the stigma surrounding their diagnoses, given its potentially negative impact on their lived experiences. Recent research has demonstrated that students believe others would have a negative opinion of someone receiving mental health care and that students with disabilities often confront pushback and hostility when seeking academic accommodations (The Healthy Minds Network [HMN], 2022; Zongrone et al., 2021). Students have disclosed experiences encountering people with ableist mindsets when requesting academic accommodations from faculty and staff, such as being told they are looking for an unfair advantage or a means to "cheat" the system (Zongrone et al., 2021). This fear of being perceived and treated differently by others in academia can hamper students' help-seeking behaviors, which, in turn can, prevent them from accessing tools and resources that help them persist both personally and academically (Eisenberg, Downs, et al., 2009; Zongrone et al., 2021).

2.2.2 Academic Impact

The short and long-term effects of mental health problems on students' academic performance can have dire impacts on student outcomes. Depression causes significant cognitive impairment, affecting executive function, memory, and attention, not confined to depressive episodes (Rock et al., 2014). Even mild forms of depression predict lower cognitive function that can worsen with time (Dotson et al., 2008; Laukka et al., 2018). Mental health problems have a lasting negative impact on student outcomes, including social connectedness, academic performance and retention, and future economic productivity (Lipson et al., 2016). Depression, anxiety, and eating disorders all strongly predict lower grade point averages, with comorbidity of depression and anxiety predicting stronger impacts (Eisenberg, Golberstein, et al., 2009). A study conducted in the United Kingdom found a correlation between depression and lower performance on exams

(Andrews & Wilding, 2004). Mental health problems generally predict students' being unhappy with their academic careers, wavering intentions to persist, lower confidence in degree completion, and attrition (Lipson & Eisenberg, 2018; National Alliance on Mental Illness (NAMI), 2012). Reported mental health problems double students' risk of leaving school prior to degree completion (NASEM, 2021), perhaps because of a higher risk of other negative academic outcomes.

2.2.3 Economic Impact

Mental health issues can also impair students from engaging in the workforce and thus impact global competitiveness. Untreated mental health issues can increase how long individuals experience mental health problems and the probability of relapse (Hunt & Eisenberg, 2010; Kessler et al., 2007). Unfortunately, delaying treatment after onset of a mental disorder for 10 years or more is common (Kessler et al., 2007). Thus, students who experienced onset in college are likely still living with untreated mental health issues when or if they enter the workforce. Mental health problems can negatively impact students' intentions to persist and obtain their degrees, adding to an existing shortage of skilled individuals to perform science, technology, engineering, and mathematics (STEM) jobs, dubbed the STEM Crisis (Lipson & Eisenberg, 2018; National Alliance on Mental Illness (NAMI), 2012; White House Office of Science and Technology Policy, 2014).

Mental health problems can also have detrimental costs on students' future abilities and productivity. Mental health is the third costliest disease for employers in the United States, averaging a cost of $348/employee annually (Davlasheridze et al., 2018). Over half of the reported approximately 550 million workdays lost annually due to absenteeism were stress-related (Danna & Griffin, 1999). With the rise in mental health problems resulting from the

COVID-19 pandemic, the prevalence of mental health problems is likely to increase in the coming years.

2.2.4 Impact of COVID-19

The COVID-19 pandemic has highlighted disparities and inequities that have plagued student mental health. A survey of US students found that 60% reported that the pandemic had made it increasingly difficult to access mental health care (Healthy Minds Network & American College Health Association, 2020). In a UK survey, 80% of respondents reported that their mental health had worsened due to the pandemic, and over 30% of those who were accessing mental health services in the 3 months prior to the crisis and still needed it, no longer had access (Young Minds, 2020). Currently, college counseling centers cannot meet the demand for students' mental health needs (LeViness et al., 2017). Given the shortage of mental health professionals in the United States (Thomas et al., 2009) and globally (Kakuma et al., 2011), work is needed to ensure today's college students have support in addition to traditional counseling services.

2.2.5 Graduate Students are Overlooked

Mental health problems significantly impact research productivity (Danna & Griffin, 1999). They can interfere with students' abilities to fulfill their graduate degree requirements and their intentions to persist. Over half of doctoral students do not complete their degree (Sowell, 2010). Surveys have demonstrated that stress, anxiety, exhaustion, and/or a lack of interest factor into these decisions (Anttila et al., 2015; Schmidt & Hansson, 2018). A recent study focusing on engineering graduate students' attrition found that intentions to persist are often impacted by more than one mental health concern (Berdanier et al., 2020); that is, the many concerns and questions that can impact students' decisions to leave engineering are often layered and interconnected (i.e., advisor role and relationship, support network, quality of life and work, cost, perception by others, goals; Berdanier et al., 2020). Research has also demonstrated that doctoral degree programs have attributes that make students want to leave. A 2017 study found that PhD students consistently reported a higher severity of mental health problems, including feeling worthless, unhappy, and depressed, as compared to peers in comparable spaces (i.e., students not in PhD programs and individuals in the general population who already have advanced degrees; Levecque et al., 2017). Likewise, research has demonstrated that the prevalence of experiencing psychological distress and having or developing a mental health problem is higher for graduate students compared to same age, highly-educated peers, indicating something unique about the graduate school process causing this (Satinsky et al., 2021).

A recent scoping literature review explored the mental health experiences of engineering graduate students (Bork & Mondisa, 2020). This work found only 19 studies on engineering graduate students' mental health through August of 2019, with most work focusing on targeting sub-groups within engineering, namely international, Black, female, and Black female students (Bork & Mondisa, 2020). International graduate students were found to be impacted by both language and cultural barriers faced by transitioning to life in the U.S. and a new educational environment (i.e., graduate school) that added to feelings of isolation and acculturative stress (Bork & Mondisa, 2020; Erichsen & Bolliger, 2011). Black, female, and Black female graduate students encountered racial-biases, gendered-biases, and both gendered- and racial-biases that directly impacted their experiences and mental health. The compounding impacts of these biases was also evidenced in Kimberlé Crenshaw's intersectionality work (Crenshaw, 1989). The most common biases were those where these students were considered less capable than their white male peers, whether they believed it about themselves or were told (implicitly or explicitly) by others in their programs (Bork & Mondisa, 2020). However, despite these findings being evident, comparison between studies was difficult due to a lack of shared terminology and mental health measures explored. Therefore, the collective claims for engineering graduate students' mental health were limited.

It is fair to ask, then, why are graduate students' mental health problems routinely overlooked? Recommendations for campus mental health services have stressed the importance of services being "of high quality and tailored to the special needs of college students" (Mowbray et al., 2006, p. 234). Yet research examining graduate students' mental health experiences is minimal, disorganized, and fragmented (Hish et al., 2019). For example, a study of biomedical doctoral students found that although they are a population at risk of experiencing severe mental health problems, little work has been done to understand these concerns (Tsai & Muindi, 2016). In addition, studies of mental health experiences do not distinguish between undergraduate and graduate students (Hefner & Eisenberg, 2009; Hunt & Eisenberg, 2010; Lipson et al., 2016; Lipson & Eisenberg, 2018; Wilson et al., 2010; Wyatt & Oswalt, 2013). These studies overlook differences across academic levels, such as varying academic and social demands (e.g., focusing on research versus courses, communicating work, goals, and career aspirations as opposed to hobbies, interests, and social activities; Wyatt & Oswalt, 2013).

2.2.6 Engineering students do not ask for help

In any discipline, students must constantly balance academic demands, personal obligations, professional aspirations, and overall health and well-being. This balancing act can impact students' willingness to seek help. Delays in seeking help can increase the length and severity of problems and decrease the effectiveness of treatment (Hunt & Eisenberg, 2010; Lipson et al., 2016). Engineering students specifically are less likely to seek help than, for example, students in the humanities or arts, while exhibiting higher stress levels and lower rates of engaging in physical activity that might help offset stress (Hyun et al., 2007; Lipson et al., 2016). This may correlate to gendered differences; women are underrepresented in engineering and are significantly more likely to consider seeking help or utilizing resources (Hyun et al., 2007). In addition, cultural stigma, personal beliefs, and systematic barriers (e.g., expensive healthcare costs, lower socioeconomic status, and insufficient health insurance coverage) can prevent students experiencing mental health problems from seeking help (Eisenberg et al., 2007). The culture of engineering, and more specifically a culture of stress, has been connected to reduced help-seeking behaviors (Jensen et al., 2023). It is possible, therefore, for these behaviors to extend into graduate student populations. Regardless, to fully understand why engineers are less likely to seek help, it is necessary to explore the culture of engineering and the potential impact it has on students' mental health.

2.3 The Culture of Engineering

The culture of engineering impacts not only how the public views engineers or how individuals learn about engineering, but how engineers themselves operate within the discipline on a national and global scale (Carberry & Baker, 2018). To situate the culture of engineering, I refer to Schein's definition, pulling from their work studying organizational culture:

> "...a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid, and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems," (Schein, 1992, p. 1).

That is, at the center of an organization's culture are the core beliefs and assumptions. These beliefs and assumptions are rarely discussed or even consciously considered. Instead, beliefs are translated into values and behavioral norms that can then be observable through actions and choices. In using this mapping, Schein describes a process to look past visible cultural manifestations (e.g., behaviors, practices, etc.) to understand the mechanisms guiding these manifestations (e.g., assumptions, values, beliefs) and vice versa (Schein, 1992).

As culture and climate are often interchanged, I define climate to be how an individual (or groups of people) interacts with and assesses a culture. It is important to note that culture, although seeming to be a separate thing, an environmental culture is enacted and enforced by individuals within the environment. That is, the culture of an environment only exists because of the social dynamics and enforcement of the culture by actors within the environment. Furthermore, these cultural norms and values can be communicated explicitly or implicitly (Villanueva, Gelles, Stefano, et al., 2018; Villanueva, Gelles, Youmans, et al., 2018). Finally, there is an inherent expectation that individuals that “fit” within a culture have a stronger alignment with these norms (e.g., alignment in the normative values, beliefs, experiences, etc.), and therefore are more likely to have a positive perception of the climate.

The following sections provide overviews of two theoretical frameworks that sought to define the culture of engineering: Cech’s culture of disengagement and Godfrey and Parker’s culture of engineering education. Using Schein’s mapping, Cech’s framework focuses more on providing a rich understanding of the underlying beliefs and assumptions core to the culture of engineering. Godfrey and Parker’s framework, on the other hand, emphasizes observable actions and behaviors that represent the enactment of the culture of engineering. As this dissertation is looking to connect the culture of engineering to students’ experiences with mental health, I leveraged Godfrey and Parker’s framework. However, to understand the context of this framework, it is also necessary to understand the underlying beliefs of the culture of engineering.

Therefore, in the following sections, I first detail Cech's culture of disengagement and define the three central cultural beliefs that make up this theory. To connect these beliefs to observable actions and behaviors, I also provide a synthesis of literature that demonstrates how each belief translates to values, actions, and behaviors within engineering. I then provide an overview of Godfrey and Parker's framework and how others have used this framework to explore students' mental health experiences.

2.3.1 A Culture of Disengagement

Through a longitudinal study, Cech worked to examine and define the culture of engineering (2014). Cech found that engineering has a culture of disengagement, based on a widespread belief that engineering work lies outside and tangential to public welfare concerns (2014). Cech based this culture of disengagement on three core beliefs: (1) engineering work is unrelated to social or political concerns (i.e., depoliticization), (2) social competencies are outside of and secondary to the core technical engineering competencies (i.e., socio-technical dualism), and (3) an individual's success within engineering is directly attributable to the work and effort they have put into their work (i.e., meritocracy). These beliefs, although core to engineering, can be difficult to directly observe. The following sections applies Schein's conceptualization of organizational culture to map these beliefs to the values and perceivable actions/behaviors that demonstrate these beliefs.

2.3.1.1 Depoliticization

As discussed, depoliticization is the belief that engineering work is unrelated to social or political concerns, or objectivity (Cech, 2014). This notion of objectivity is connected to values within scientific inquiry. That is, engineers are part of the methods used to conduct research and therefore need to be value neutral in their application of math and science to not "taint [the] otherwise pure engineering design methodologies" (Cech, 2014, p. 71). This belief in objectivity translates to the value within engineering where engineers should strive to be as objective and neutral as they are able when conducting engineer work. This value translates into behaviors, where, as put by Cech, engineers can have cognitive dissonance between the work they and the real-world social implications and complications of the work (i.e., these aspects get defined out of engineering work; Cech, 2014). This behavior, where individuals are expected to conduct their engineering work (e.g., make decisions, recommendations, perform analysis, etc.) while intentionally separating their own values and beliefs has been explored within engineering.

The enactment of this belief is prevalent when exploring students' interests for joining STEM disciplines. Minoritized students within STEM are known to be motivated by altruistic and community-oriented goals (Brawner et al., 2015; Carlone & Johnson, 2007; Chesler & Chesler, 2002; Colvin et al., 2013; Diekman et al., 2010, 2015; Garibay, 2018; McCormick et al., 2014; McGee et al., 2016; J. L. Smith et al., 2014; Thoman et al., 2015). That is, many minoritized students within STEM enter with the hopes of learning the skills and tools to help others within their communities. However, these minoritized students have found there to be a disconnect between these values and engineering which leads to tensions for students (Cech, 2014; Diekman et al., 2010; J. L. Smith et al., 2014). This disconnect and tension is known to impact minoritized students' engagement and persistence within engineering. That is, if a student perceives that the values they hold are not accepted or welcomed within engineering, this can lower a students' sense of belonging and desire to persist within the field (Bork & Mondisa, 2020; Fisher et al., 2019; Marra et al., 2012; Museus et al., 2017).

2.3.1.2 Socio-technical dualism

Socio-technical dualism is the belief within engineering that social competencies are outside of and secondary to the core technical engineering competencies (Cech, 2014). This belief translates directly to the type of work that is counted as engineering work. That is, technical work within engineering is regarded as legitimate engineering work, whereas work that includes social, interpersonal, or contextual elements are not counted (Faulkner, 2007; Nieusma & Riley, 2010). This value translates to behaviors where engineers can again discredit and ignore public welfare concerns within engineering works as these concerns fall on the social end of this continuum (Cech, 2014). Examining engineering students' mindsets revealed how an engineer's critical thinking skills extend to technical analysis but overlooks the social context the work falls under (Riley, 2008). Furthermore, this removes an individual engineer's accountability for how their work may ultimately be used (Riley, 2008). These behaviors are taught to future engineers as they are socialized into the discipline and learn what practices are considered engineering.

The enactment of socio-technical dualism can be demonstrated by examining gendered differences within engineering. Tonso performed an ethnographic study of an engineering department that detailed how individuals within engineering enforced gendered norms of engineering work and identities (Tonso, 2006). When describing the different identities engineering students could assume, women were found to be confined to a sub-set of feminine identities that more than likely prevented them to be recognized as "real" engineers (Tonso, 2006). Cultures within engineering sub-fields, unsurprisingly, differ in their acceptance of female students, and have been demonstrated to impact the disciplines female students enter (Godfrey, 2007). Furthermore, technical skills within engineering are thought of as hard and masculine whereas non-technical skills that are devalued are coded as feminine and "soft" skills; this coding enforces norms where woman engineers must continuously re-establish their prominent identity in these spaces as an engineer over being a woman (Faulkner, 2007; Nieusma & Riley, 2010).

2.3.1.3 Meritocracy

Meritocracy is the belief that an individuals' success within engineering is directly attributable to the work and effort they have put into their work as the systems for advancement are fair and just (Cech, 2014). That is, individuals who succeed and progress do so because of the hard work they have done. A recent narrative analysis of the culture of engineering echoed these findings (Sochacka et al., 2021). They found that this belief of meritocracy translated to values of hard work and perseverance as this would result in both recognition and generous compensation if they could succeed (Sochacka et al., 2021). Others have also found success in engineering to be entrenched in this value of hard work, with expected behaviors centered on enduring and surviving the constant struggle and difficulty of engineering (Godfrey & Parker, 2010; Rohde et al., 2020; Secules et al., 2018).

The enactment of the meritocracy can be demonstrated by examining definitions of success within engineering. Research exploring who can do engineering found that although students acknowledge anyone can be an engineer, in practice there are many exclusionary criteria an individual must meet (e.g., endure hard work, commitment to engineering) and qualities an individual would need to possess (e.g., have discipline) to become an engineer (Rohde et al., 2020). Their findings highlighted how participants defined two sets of students: those who innately had what it takes to succeed, and those who would need to work substantially more as they lacked, and always would lack, these qualities (e.g., brain power an individual is born with; Rohde et al., 2020). When exploring the relationship between the difficulty of engineering and students' motivation, Rohde et al. found that difficult tasks served to strengthen pre-existing identities; those who had a strong identity as an engineer felt a deeper motivation for their work, whereas those without a strong alignment between the work and their identity felt that this difficulty further proved they did not belong within engineering (Rohde et al., 2020). The belief of meritocracy translating into exclusionary practices was also found when examining students seeking academic accommodations. When considering behaviors of help-seeking within engineering, students with mental health problems are often concerned with how others may perceive them and worry that others on campus will view them as lesser (The Healthy Minds Network (HMN), 2021; Zongrone et al., 2021). Students requesting disability related accommodations, whether apparent or not, often needed to overcome hostility from faculty and staff as they believed students were seeking an unfair advantage (Zongrone et al., 2021). That is, students' needs for accommodations were not seen as justified, but rather as an unfair way students would bypass their own personal failings as a student performing poorly academically (Zongrone et al., 2021). This deficit framing in conjunction with exclusionary practices communicate to students that the difficulty they face is the same as every other student, and that if they want to fit within engineering, they need to prove themselves by enduring it (Godfrey & Parker, 2010; Zongrone et al., 2021).

2.3.2 The Culture of Engineering Education Framework

Godfrey and Parker developed a conceptual framework to map the culture of engineering education, which I refer to as the Culture of Engineering Education Framework, or CEEF, in the remainder of this manuscript (Godfrey & Parker, 2010). They sought to develop a framework to situate engineering education and to understand dimensions of the culture of engineering, including the goals of the discipline and believed pathway to achieve those goals (Godfrey &

Parker, 2010). This work was guided by an adaptation of Schein's cultural framework (Schein, 1985, 1992). That is, culture was centered on unobservable and often unconscious beliefs and assumptions. These beliefs and assumptions instead translate to values, which are observable through behavior. In addition, Godfrey and Parker specify the temporal nature of culture in their adaptation of Schein's cultural framework. That is, they state that "culture is not static but open to shifting values and cultural norms. Any snapshot of a culture will therefore be situated at a particular place and time," (Godfrey & Parker, 2010), p. 7).

Guided by Schein's recommendations, an ethnographic research study was used to collect data. Specifically, a case study within the school of engineering at a "large, high ranking, research-led university in New Zealand" was conducted, with most data collected in 1998 (Godfrey & Parker, 2010, p. 7). Godfrey and Parker used an overarching interpretivist research approach to understand not only what the culture of engineering education was but why things were done the way they were. Their findings revealed six dimensions of engineering education: an engineering way of thinking, an engineering way of doing, being an engineer, acceptance of difference, relationships, and relationship to the environment. Figure 2-1 provides a visual representation of this framework, and Table 2-1 provide an overview for each of the six dimensions in the framework. The following section will walk through these six dimensions and the themes that fall under each dimension.

2.3.2.1 An Engineering Way of Thinking

An Engineering Way of Thinking encapsulates the unique ways of conceptualizing or knowing information specific to engineers. There are five themes under this dimension: *math is infallible, innocent, and/or pure; strong prevalence of visual communication; problem-solving and design;*

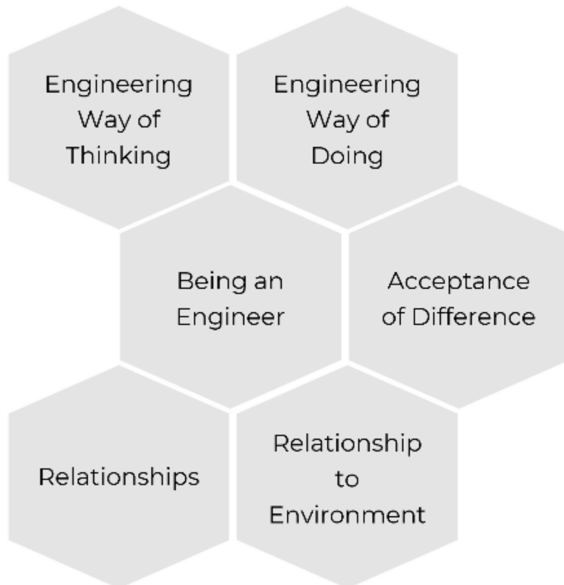

Figure 2-1. Culture of Engineering Education Framework (CEEF; Godfrey & Parker, 2010).

Table 2-1. Overviewing the six dimensions of Godfrey & Parker's Culture of Engineering Education Framework (CEEF; Godfrey & Parker, 2010).

Dimension	**Overview**
An Engineering Way of Thinking	Unique ways of knowing or conceptualizing information as an engineer
An Engineering Way of Doing	Beliefs and/or assumptions on how teaching and learning occurs within engineering education
Being an Engineer	Common attributes and/or attitudes associated with being an engineer
Acceptance of Difference	Considering the homogeneity and/or diversity of thoughts and/or values within engineering
Relationships	What relationships exist and/or the appropriate ways relationships are established and maintained within engineering
Relationship to Environment	Assumptions and beliefs held regarding engineering education's operation within several environments, including a campus environment, an institutional environment, the broader environment of higher education, engineering as a profession, and the cultural landscape of the geographic location (e.g., politics, economics, etc.)

working to find the "best" not "right" answer; and *objectiveness with math and science.* Table 2-2 provides a definition of each of these themes.

Table 2-2. Overviewing dimension *An Engineering Way of Thinking* (Godfrey & Parker, 2010)

Theme	Definition
Math is infallible, innocent, and/or pure	Math is reality. It can't lie or be biased. Engineers trust in math.
Strong prevalence of visual communication	Work done is usually definable and measurable. Rely on graphics, diagrams, or other visuals to transmit knowledge. Verbal communication can support it, provide order, justification, ideologies, but not primary source of knowledge.
Problem solving and design	Engineering thinking is dominated by reductionist and top-down methods (i.e., breaking down into tangible components) for problem solving. Often guided using mathematical formulae and/or estimation. Design is used to exercise and apply knowledge on engineering applications.
"Best" not "right" answers	Use of contextual factors to drive the answer. Mathematical assumptions or models help calculate and answer and define the problem space. At the same time, external demands and/or assumptions can alter the confines of the problem, and therefore drive which answer is "best."
Objectiveness with math and science	This is an assumption that the mathematical procedures, scientific processes, and the laws on which problem solutions were based were race and gender free. Therefore, when using math, it is also race and gender free, regardless of methods or user (e.g., problem solving, teaching, or assessment).

2.3.2.2 An Engineering Way of Doing

An Engineering Way of Doing refers to commonly held assumptions and beliefs in how teaching and learning occurs within engineering education. There were seven themes under this dimension: *hardness; take it; approach problem-solving using a toolkit; professional development is conditionally valued; cooperation and competition are accepted within engineering; education is used for credentials;* and *time is a resource to be managed.* Table 2-3 provides a definition of each of these themes.

2.3.2.3 Being an Engineer

The dimension of *Being an Engineer* is defined by common attributes and/or attitudes associated with being an engineer, rooted in the belief that there are inherent qualities attributed to engineers that fit in and succeed within engineering. There were six themes under this

Table 2-3. Overviewing the dimension *An Engineering Way of Doing* (Godfrey & Parker, 2010)

Theme	Definition
Hardness	The difficulty and hardness of engineering and its curriculum in innate, valued, and respected. It is acknowledged that not everyone will be able to make it. Furthermore, engineers de-value work/disciplines that are easy or soft are not as valuable. This is also a gendered aspect, where hard is coded as masculine and soft is coded as feminine.
Take it	Those who wish to enter the profession need to accept the difficulty and endure it, or are considered not fit for the field. Learning is equated to suffering and hardship, and being able to endure and succeed in this environment leads to a bootcamp mentality and shared sense of pride and achievement for having made it.
Approach problem-solving using a toolkit	Engineer's education is centered on gaining expert knowledge and a "tool bag" of skills that can then be applied to solve any problem.
Professional development is conditionally valued	Professional development is viewed as a nontechnical skill, separate from engineering concepts and curriculum. It is considered soft and easy, and therefore only valuable within engineering professional settings when/where the skills are useful.
Cooperation and competition are accepted within engineering	Competition and cooperation are accepted within engineering. Students compete for grades and opportunities. At the same time, students share in their suffering, and can choose (or at times have no other option) than to work together to survive their program.
Education is used for credentials	The degree and education in engineering are valued as they provide proof of a qualification. Once obtained, this provides opportunities.
Time is a resource to be managed	Time is a resource to be managed. This is paired with a learning environment that has a heavy workload and stringent time constraints/deadlines on the workload. Therefore, despite time being often constrained and limited, individuals are expected to manage this and meet expectations set.

dimension: *"can-do" attitude; think in bullet points; stereotypes; all or nothing; being one of the "guys";* and *pride in being an engineer*. Table 2-4 provides a definition of each of these themes.

Table 2-4. Overviewing the dimension *Being an Engineer* (Godfrey & Parker, 2010)

Theme	Definition
"Can-do" attitude	Those who enter engineering are high achievers, above average in math and science, and proactive towards problem solving. If perceived to fit this criterion, you will be trusted by peers. This is demonstrated in the ability to divide and delegate tasks with the trust they will be completed to expected standards.
Think in bullet points	Engineers think in bullet points. They value logic, and communicate in a step-by-step, organized fashion rather than descriptive, flowing sentences.
Stereotypes	Engineers typically follow a set of characteristics: numerating, practical, mentally tough, emotionally steady, conservatively mannered, pragmatic, self-depreciative, and unconcerned with appearance.
All or nothing	Engineers throw themselves into whatever activity they are doing, whether that be work or relaxation (work hard, play hard).
Being one of the "guys"	Engineering is a male-dominated field. With that comes expected behaviors (e.g., profane language, semi-sexual innuendos, sport metaphors, etc.). Women, even if respected in the discipline, are othered and viewed under a misogynistic lens.
Pride in being an engineer	Engineers believe in a meritocracy, and as part of a group that works hard, there is this shared mentality that culminates in a sense of pride and solidarity of belonging to that group. This manifests itself in language, publications, dress, how they see themselves compared to the rest of the university, and the discourse around framing the degree as "hard."

2.3.2.4 Acceptance of Difference

The dimension *Acceptance of Difference* discusses homogeneity and/or diversity of thoughts and/or values within engineering, and whether diversity is desired. There were four themes under this dimension: *homogeneity, conditional acceptance, first impressions,* and *prove yourself.* Table 2-5 provides a definition of each of these themes.

Table 2-5. Overviewing the dimension *Acceptance of Difference* (Godfrey & Parker, 2010)

Theme	Definition
Homogeneity	There is a high degree of homogeneity within the attitudes, beliefs, norms, and values engineers are expected to hold and/or conform to. There is also an assumption the engineers have similar backgrounds and experiences (e.g., education).
Conditional acceptance	Individuals are always being assessed for inclusion, and those with differences may feel it is conditional based on their ability to assimilate and/or hide/downplay what makes them different and conform to aspects under the dimension *being an engineer*.
First impressions	Within engineering, individuals initially form relationships based on what they perceive other's abilities are within engineering and how much they expect them to succeed and/or support their own personal success. Initial relationships are based on shared interests and backgrounds as these can be leveraged as social capital and build trust, and at the same time, are usually biased by personal biases and prejudices. Minoritized individuals find that acceptance and respect for them within the discipline to be a slow, painful, and long process as their backgrounds and experiences were atypical within engineering, accentuating them as different.
Prove yourself	Individuals may change their perceptions and/or level of acceptance for "others" who persist within engineering after they have sufficiently proven their abilities, often combating unspoken prejudices and biases and/or being forced to assimilate (i.e., burden of proof on othered individual to show not what they expect them to be).

2.3.2.5 Relationships

Relationships as a dimension discusses the relationships that exist within engineering education, as well as the appropriate way these relationships are established and maintained. There were three themes under this dimension: *collaborative; mates;* and *student-faculty interactions*. Table 2-6 provides a definition of each of these themes.

2.3.2.6 Relationship to Environment

The dimension of *Relationship to Environment* acknowledges that engineering education operates within several additional environments (i.e., a campus environment, an institutional

Table 2-6. Overviewing the dimension *Relationships* (Godfrey & Parker, 2010)

Theme	Definition
Collaborative	Engineering is largely collaborative and stems from a shared struggle mentality. The degree of collaboration can vary based on the situation and institution's priorities.
Mates	It behooves students to form friendships with peers in engineering (e.g., difficulty of academics, time constrained, time will spend in engineering, be seen as belonging). Not doing so can increase difficulty of major and ostracize them.
Student – faculty interactions	Students are aware of the power and generational differences that exist between them and staff/faculty. At the same time, as teaching/mentoring relationship develops, trust and rapport can build allowing for interactions to become more informal (blur differences).

environment, the broader environment of higher education, engineering as a profession, and the cultural landscape of the geographic location), and that there are assumptions and beliefs about how these environments interact with engineering education. There were three themes under this dimension: *situated within several embedded ecosystems; desire for autonomy and independence;* and *inherent oversight.* Table 2-7 provides a definition of each of these themes.

Table 2-7. Overviewing the dimension *Relationship to Environment* (Godfrey & Parker, 2010)

Theme	Definition
Situated within several embedded ecosystems	An individual student's experience within engineering are shaped by (1) the academic environment of higher education at their own institution, (2) degree of oversight and/or involvement of the engineering profession, and (3) the cultural landscape of the nation (including political, economic, and social contexts).
Desire for autonomy and independence	Within an academic institution, engineering strives for autonomy, independence, and minimal oversight, and preference for resolving issues internally.
Inherent oversight	Although engineering desires to be self-sufficient with minimal oversight, it is still overseen by a university and held to governmental (local, state, national) and funding agency regulations.

2.3.2.7 Applicability of CEEF

The CEEF provides a clear mapping of dimensions and themes that represent the culture of engineering. Furthermore, as discussed, this framework was designed to help examine behavioral enactments of engineering values that are founded on often undiscussed and/or unconscious beliefs and assumptions (Godfrey & Parker, 2010). I leverage this framework in the second half of my dissertation (i.e., Chapters 4 and 5) to ground my exploration of the culture of mental health for engineering graduate students.

Recent work has applied this framework to explore the role of culture in engineering students' mental health. For example, Jensen, Cross, and others have leveraged this framework to motivate studying cultural factors related to undergraduate engineering students' mental health (Jensen et al., 2023; Jensen & Cross, 2021; I. Miller, 2022; Mirabelli et al., 2020). Others have used measures developed by Jensen & Cross (2021) to evaluate engineering stress culture within project-based learning programs (Chase et al., 2022). Others have also used this framework to situate research exploring sociocultural expectations for students with disabilities within U.S. undergraduate civil engineering programs (McCall et al., 2020). This work has established the strength in this framework in providing a framework that defines the culture of engineering.

Chapter 3 Engineering Graduate Students' Mental Health: A Scoping Literature Review[3]

This chapter will present an overview on engineering graduate students' mental health literature through August of 2019. I investigated the literature concerning engineering graduate students' mental health, focusing on academic outcomes, mental health measures, and mental health findings, to highlight gaps in current literature and the need for further research. To do so, I identified and synthesized the literature examining US engineering graduate students' mental health using the scoping literature review process (ScLRs; Arksey & O'Malley, 2005; Grant & Booth, 2011; Samnani et al., 2017), as discussed in a previously published conference proceeding (Bork et al., 2019).

I describe the methods used to conduct this ScLR, including how five research databases (i.e., EBSCO: CINAHL, EBSCO: PsycINFO, ProQuest: ERIC, PubMed, and Scopus) were searched to yield 4,826 unique studies. I detail how these studies were screened using the inclusion and exclusion criteria before collecting data on each study (i.e., study focus, keywords, participants and institution(s), journal discipline, study type, methods used, work referenced, academic outcomes, mental health measures, and mental health findings). After discussing the methods, I detail findings across the 19 studies included in the review, including the ten academic outcomes, 13 mental health measures, and five themes of mental health findings (i.e., social support and sense of belonging; student–advisor relationship; cultural barriers faced by international students; gender and racial stereotypes; and generalized findings). I then overview

[3] Bork, S. J. & Mondisa, J.-L. Engineering Graduate Students' Mental Health: A Scoping Literature Review. *Journal of Engineering Education*, 111(3), 665-702. https://doi.org/10.1002/jee.20465

the limitations of this study before discussing the findings with relevant literature, implications for the field of engineering education, and future research and practices. Overall, this study found that research on engineering graduate students' mental health through August 2019 was limited. Recommendations for future work focused on the need to examine students' mental health experiences, sharing these findings, and communicating best practices for all stakeholders engaged in this work.

3.1 Methods

There are many similarities between ScLRs and systematic literature reviews. Both include searches of completeness determined by time and scope restraints; neither have formal quality assessments, and analysis includes characterizations of the quantity of literature, quality of literature, study design, and key features (Grant & Booth, 2011). A major difference, however, is that a systematic review includes appraisal mechanisms to assess and set a minimum quality for studies included in the review, whereas ScLRs do not. ScLRs are performed to learn the extent of research that has been conducted in a specific field, typically with broader research questions guiding the study, with the main objective of synthesizing and reporting on existing literature (Grant & Booth, 2011).

This ScLR had five stages, as detailed in Table 1 (Arksey & O'Malley, 2005; Bork et al., 2019). Table 3-1 features details about each stage, including its main objectives and outcomes. A librarian who specializes in literature review searches provided guidance for this review by refining the research questions, helping select databases, aiding the development of the search protocol, and providing resources to guide the entire process. I describe each stage in the sections that follow.

Table 3-1. The five stages of an ScLR (generated from Arksey & O'Malley, 2005).

Stage	Objective	Outcomes
1: Identify the research question(s)	Determine scope of project and focus for search.	Inclusion and exclusion criteria
2: Identify relevant studies	Determine relevant sources of literature.	References for study
3: Study selection	Define screening process.	Eligible references
4: Charting the data	Coding the literature and record vital information.	Literature data for analysis
5: Summarize and report results	Condense and organize all information collected into a coherent report.	Identify of current literature trends and potential research gaps

3.1.1 Stage 1: Identify the research question(s)

In this stage, the research question was formed: *What is the current landscape of literature about engineering graduate students' mental health?* This question helps situate the context of the study, as evidenced in the formation of the study's three central inclusion criteria: the study must (1) discuss graduate students, (2) include engineering students, and (3) discuss the mental health of these students. Graduate students were defined as any student working towards a master's or doctoral degree, with mental health being defined as anything related to a person's emotional or psychological well-being. The working definitions and example search terms are detailed in Table 3-2. Additional inclusion/exclusion criteria were used to determine if studies should be included in the review. Studies were excluded if they did not come from a peer-reviewed source, were not written in English, or did not focus on students studying in the United States. The only restriction on publication date was the date of the second and last search (August 6, 2019). Table 3-2 includes the working definitions and how these criteria were implemented in the review process.

Table 3-2. Inclusion and exclusion criteria used to guide the ScLR

The three central inclusion criteria

Inclusion criteria	Working definition	Example search terms
Graduate students	Any student working towards a master's or doctoral degree (e.g., PhD, MS).	Graduate education, doctoral, master's, PhD AND student, candidate
Engineering	Any discipline included in engineering.	Engineering
Mental health	Anything related to a person's emotional or psychological well-being.	Mental health, depression, anxiety, wellness, quality of life

Additional inclusion/exclusion criteria

Inclusion/Exclusion criteria	Working definition	How implemented
Peer-reviewed	Article or conference paper part of a peer-review process for publication	Verifying published with peer-review process (e.g., not blogs or grey literature)
Written in English	The publication needed to be available in the English language	Database search restriction
U.S. students	Any student studying in the U.S.	Study participants needed to include U.S. students; screening stages
No date range	Any date range on the publication	All publications until the date of the literature search included (March 12, 2019, and August 6, 2019)

3.1.2 Stage 2: Identify relevant studies

Five databases were used to search for articles: EBSCO: CINAHL, EBSCO: PsycINFO, ProQuest: ERIC, PubMed, and Scopus. These databases were selected with guidance from a librarian. Collectively, they cover a breadth of areas that are relevant to the research question, including allied health literature, biomedical science, behavioral science, education, health sciences, life sciences, mental health, nursing, physical sciences, psychology, public health, and social sciences. Search protocols were developed using the three central inclusion criteria, yielding the following general search block for all fields: ("engineering") AND ("doctoral" OR "master") AND ("student") AND ("mental health" OR "well-being" OR "depression" OR "anxiety"). Other example search terms are featured in Table 3-2, with the full search terms used for each database available online in Supporting Information S1 (Bork & Mondisa, 2022) and in Appendix A. Guided by the inclusion and exclusion criteria detailed in Table 3-2, the first author performed the database searches on two separate occasions. These searches resulted in the 4826 unique articles that formed the basis for the screening and selection process for this review. The following sections detail the screening and selection process that followed. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram illustrated in Figure 3-1 provides a visual overview of this review's complete search and screening processes.

3.1.3 Stage 3: Study selection

For this stage, I created screening questions to enforce the inclusion and exclusion criteria. The screening questions for each step are featured in Table 3-3. The selection process had four steps: title screening, abstract screening, full-text screening, and full-text eligibility. The first three steps were exclusionary screening stages. They were intended to exclude any study that clearly did not fit one or more of the criteria. This also meant that unless a study clearly contrasted inclusion criteria, it would be included. The last step, full-text eligibility, was an inclusionary process. This meant that the screening questions were made dichotomous, and a “yes” was needed to include the study; that is, the studies needed to clearly meet the inclusion criteria to be included. The researchers ran the search protocol twice; first on March 1, 2019, and second on August 6, 2019.

For data collection, title screening was completed using the systematic literature review software DistillerSR due to the volume of titles and interfacing provided (Evidence Partners, 2022). The reviewers used the software to screen the study titles independently; the responses were recorded and downloaded to a Microsoft Excel sheet, which was used for comparisons. This sheet was used to gather the titles for the abstract screening, where the same process for data collection took place. Google Forms were used for the data collection for full-text screening,

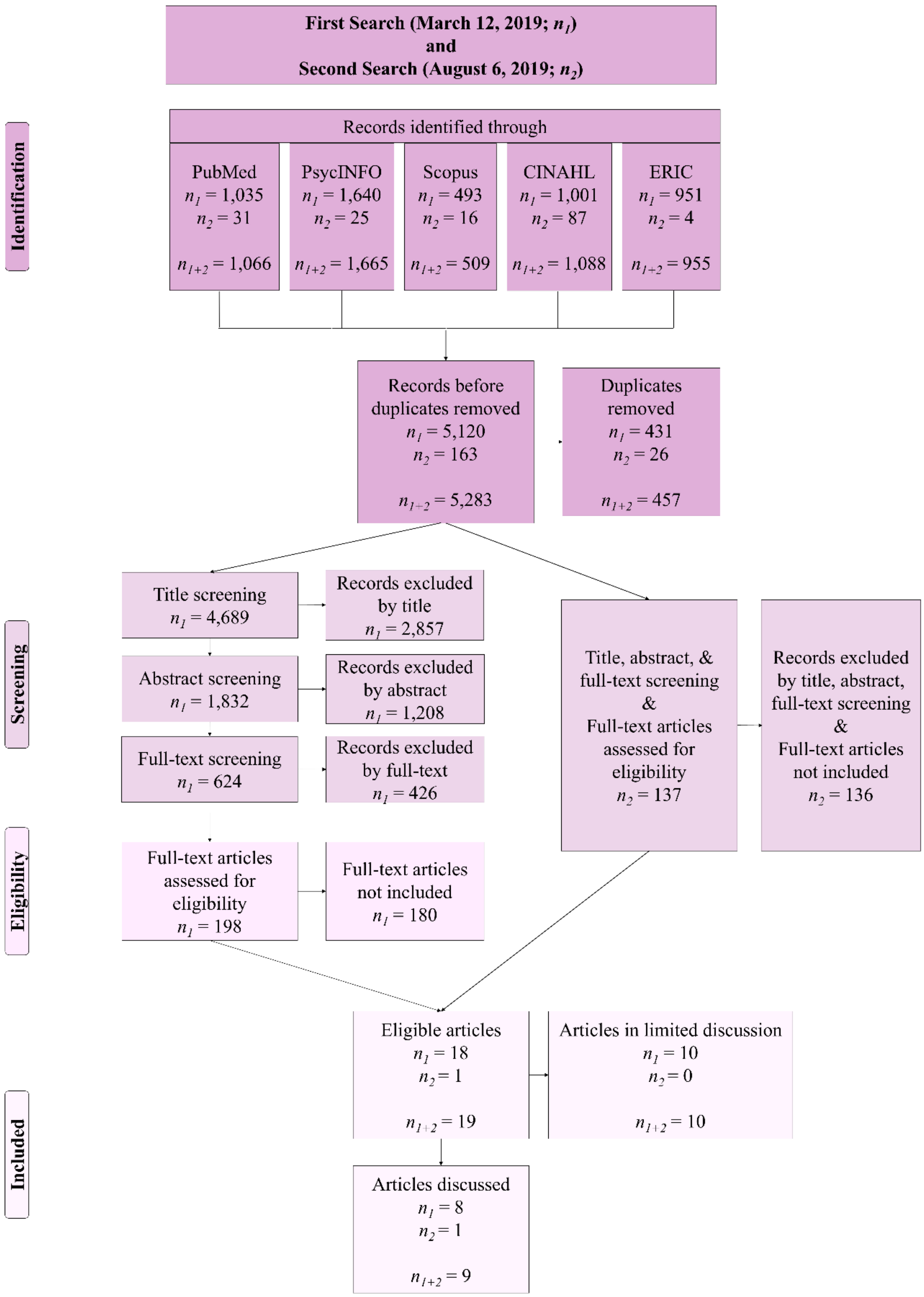

Figure 3-1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram demonstrating the search and separate screening process of studies to be included in this review. Details the cumulative results from the first search conducted on March 12, 2019, (n_1) and the second search conducted on August 6, 2019, (n_2).

Table 3-3. Screening questions used in the ScLR to enact the inclusion/exclusion criteria.

Step	Screening question(s)	Response for inclusion	Reviewers' agreement for March search	Reviewers' agreement for August search
Title screening	Is the title relevant?	Yes, Not Sure	One & two screened independently, discrepancies discussed; 79% agreement rate	One & two completed all stages of screening independently; compared final included papers and discussed any disagreement
Abstract screening	Is this abstract focused on students in the US?	Yes, Not Sure	One & two screened training sets of 10 and 20 studies independently until 80% agreement reached; three rounds required (50 studies in total)	
	Does this abstract include only those in clinical practices (medical training, nursing, veterinarian, etc.)?	No, Not Sure		
	Does the abstract discuss mental health?	Yes, Not Sure		
	Are graduate students a major focus of this study?	Yes, Not Sure		
	Are Engineering students a major focus of this study?	Yes, Not Sure		
Full-text screening	Is this study focused on students in the US?	Yes, Not Sure	One, two, & three screened training sets of 5 and 10 studies independently until 100% agreement reached; four rounds required (35 studies in total)	
	Does this study include those in clinical practices (medical training, nursing, veterinarian, etc.)?	No, Not Sure		
	Does the paper discuss mental health?	Yes, Not Sure		
	Are graduate students a major focus of this study?	Yes, Not Sure		
	Are Engineering students a major focus of this study?	Yes, Not Sure		
	Where was this article published?	Any peer-reviewed publication		
Full-text eligibility	Is this study focused on students in the U.S.?	Yes	Two & three reviewed independently, bringing in one on any discrepancies; all final papers reviewed together for 100% agreement	
	What mental health terms are used?	Any non-chronic ailment		
	What degree programs are the students a part of?	Masters, doctoral, graduate		
	What disciplines are explicitly stated?	engineering		
	Where was this article published?	Any journal publication		
	Are engineering graduate students included in the article?	Any response		

full-text eligibility, and all inter-rater reliability checks as Google Forms connects directly to Google Sheets, making for easy comparisons.

Three reviewers screened across both searches. Table 3-3 illustrates a summary of the process for both searches. The first researcher is the first author of this publication and was the main reviewer and lead for the project. The second and third researchers both assisted in the project, with the third researcher joining the team after the title screening stage and leaving before the August search was conducted. Although the August search was conducted by a smaller study team, there was a lower number of studies to screen, and the reviewers were able to build on their experiences from the March search. Given this, during the August search, the first and second reviewers completed the title screening, abstract screening, full-text screening, and full-text eligibility screening independently. The same process for screening the studies was followed (excluding the inter-rater reliability checks) as detailed in Table 3-3. However, as a result, only the aggregate data for the August search was available and presented in the screening process in Figure 3-1. For the sake of clarity, the following sections on title screening, abstract screening, and full-text screening only provide details for the March search, with the full-text eligibility section providing details from both.

3.1.3.1 March: Title screening

The 4689 titles were screened by answering the question, Is the title relevant? (Yes, No, Not Sure). The reviewers interpreted this to mean "Does the title make a statement that directly conflicts with an inclusion item?" The first and second reviewers independently screened all the study titles. During reviewing, any large uncertainty or discrepancy in the criteria was discussed. Once the screening was completed, the responses from the two reviewers were compared. Any discrepancy (a yes/no or yes/not sure pairing) was noted and then screened jointly by the first and second reviewers, ensuring that any uncertainty with the inclusion/exclusion criteria was clarified. The reviewers had a 79% agreement rate on the inclusion of papers to the next screening stage. From the title screening, 2857 studies were removed, lowering the number of studies from 4689 to 1832.

3.1.3.2 March: Abstract screening

Five questions were used in this step. For measuring the level of agreement between the first and second reviewers, subsets of the articles in the screening stage were made into training sets. The reviewers first started by independently screening the first training set (10 studies). Responses for study inclusion were compared, with any differences in inclusion between reviewers discussed until an agreement was met and the underlying inclusion/exclusion criteria were clarified. The following training sets included 20 studies, and this process of independent screening, comparing, and discussion continued until the reviewers came to at least an 80% level of agreement (Bradley et al., 2007). This was done for two rounds, or a total of 50 studies discussed. Also, at the end of the abstract screening, both reviewers used the final 20 studies as a training set to again assess the level of agreement. Next, the first and second reviewers divided and screened the remaining abstracts, communicating as needed for clarity or assistance throughout the process. There were 1208 studies removed at this stage, reducing the number of studies from 1832 to 624.

3.1.3.3 March: Full-text screening

Six questions were used at this step. Before the screening could begin, the full text of each study needed to be downloaded. The first and third reviewers matched the reference numbers of the studies that passed the abstract screening to the title and authors of each article so they could be downloaded. All three reviewers then participated in the screening process. As with the abstract screening, reviewer agreement was measured to allow for the screening to be split. All three reviewers screened, compared, and discussed the first training set, consisting of five studies. The same process followed with sets of 10 studies until all three authors agreed on the inclusionary status for the 10 studies (agreement reached 100%). This took three sets of 10, with a total of 35 papers being discussed. After an agreement was achieved, the remaining papers were split between the three reviewers. This screening stage removed 426 studies, leaving 198.

3.1.3.4 August: Title, abstract, and full-text screening

The same screening process was followed as in the March search. Although the August search was conducted by a smaller study team, there was a lower number of studies to screen, and the reviewers were able to build on their experiences from the March search. During the August search, the first and second reviewers completed the title screening, abstract screening, full-text screening, and full-text eligibility screening independently. They only checked in to discuss confusion on agreement criteria and then at the final step to discuss the papers to be included in the study (as detailed in Table 3-3). As a result, only the number of studies included in the review is discussed in the following section.

3.1.3.5 March and August: Full-text Eligibility

At this point in the review, a study could only make it to the data extraction and analysis stage if it clearly met all the inclusion criteria, verified through the screening questions. The first five questions included in this section were used to determine eligibility. The sixth question was added to the screening because of discussions by reviewers surrounding the first full-text screening: Are engineering graduate students included in the article? (Yes, No); that is, when screening, I found that engineering graduate students may be included in a study without being explicitly discussed in the results or analysis. Thus, no findings could be clearly attributed to the population of interest. The question did not affect the inclusion of the article in the study, but it is important to note if the population of interest was indeed singled out in the analysis and/or discussion.

For this final stage of the March search, the studies were split between the second and third reviewers and screened concurrently. If any level of uncertainty arose, all three reviewers would discuss it together and add clarifications to the inclusion and exclusion criteria. All three reviewers then read the final round of included studies, checking each for eligibility. The same process as the August search was used, except only the first and second reviewers were involved in the process. One common reason for the rejection of a study was a lack of clarity as to whether engineering graduate students were included in the study sample (i.e., papers with engineering students and graduate students, but no indication of overlap between the categories). From the March search, 180 studies were removed in the final stage, leaving 18 studies; only one study remained from the August search. From these 19 eligible studies across the two searches, nine studies differentiated engineering graduate students in the results.

3.1.4 Stage 4: Charting the data

The main objective for this step was to collect the information of interest from each of the studies included. This was done via a coding rubric designed to extract key points of the data. The inclusion and exclusion criteria were used to operationalize the screening questions to ensure these topics were discussed. The coding rubric served to expand upon these topics and determine the degree to which they were expressed across the studies. Initially, the coding rubric was developed based on information the first author was expecting to find. One study was selected as a test paper and used to refine the coding rubric and resolve any confusion for the reviewers. An “other” category was used to provide space for anything not referenced in the coding rubric.

When developing the coding rubric, two categories became apparent: study information and mental health measures. In terms of items that could be categorized, study information included the study type, participant information, demographics (academic discipline, age, citizenship/nationality, gender/sex, parental education, living situation, relationship status, and year in program), cited work, and methodology. Two other items that were recorded in an open format included the study's goals and key findings. Mental health measures refer to the variables used in each study with regard to mental health; the items coded for were based on items found through the literature review or through the refinement of the coding rubric. Mental health variables included anxiety, coping habits, depression, emotion(s), existing mental health problems, life satisfaction, relationship(s), self-harm, suicidal ideation, stress, treatment utilization, well-being, and work-life balance. Any item that did not fit within the listed demographic categories or mental health variables was included in an "other" category, allowing the rubric to be updated based on the content of each paper. The first reviewer coded responses to check if any patterns appeared across studies that may have been missed. Anything that was reported in more than one study was included in the results section below. Once the rubric was completed, each reviewer independently read and coded the articles. All three reviewers then discussed each article collectively, summarized the information, and checked for consistency.

3.1.5 Stage 5: Summarize and report results

The final stage was to shorten and summarize the key findings from each of the 19 studies. This was done via an in-person group discussion to ensure that the information gathered was accurate. The reviewers collectively distilled each study's information into key points collectively to ensure everyone agreed with the final output. This information is reported in the results section.

3.1.6 Research team positionality

The positionality of the research team is provided given its recognized impact on how research is conducted (Hampton et al., 2021; Secules et al., 2021). The authors are located at a research intensive, Midwestern, historically White higher education institution. The first author experienced all of her higher educational training in this type of environment, which impacts her perspective. Her experiences matriculating from the field of electrical engineering to engineering education research correspond to many of the cited attrition factors previously detailed. She is aware that her identities as a first-generation, white cisgender woman in engineering with her own mental health journey can lead her to seek to validate her own lived experiences. The scoping review methodology provided a framework to minimize the impact of the potential conflicts of interests and validity concerns this may bring, most notably through the consultation of a librarian with expertise in conducting reviews and the use of interrater reliability throughout the screening process. The second author is an African American woman with extensive research experience related to attrition and matriculation factors that influence students in higher education. She contributed to this work as a point of triangulation. Leveraging her research skills and knowledge, she challenged the rigor of the data analysis processes and interpretation of the findings through questions and conversations with the research team. Both authors engaged in discussions about all research aspects of the study to confirm the validity of their interpretations of the articles, the findings, and potential implications. Both Reviewers Two and Three were engineering undergraduate students in biomedical engineering and industrial and operations engineering, respectively. Although not authors of this manuscript, they contributed to this work providing validity checks by challenging the assumptions made by the first author. They also aided significantly in the screening and data extraction processes.

3.2 Results

This ScLR identifies 19 empirical studies pertaining to engineering graduate students' mental health. Table 3-4 through Table 3-10 present the results from this review. The results and summary statistics presented in the following sections (i.e., Summary Information on Included Studies, Demographic Information, Academic Outcomes, and Mental Health Measures, Instruments, and Findings) will be used to answer the guiding research question, *What is the current landscape of literature about engineering graduate students' mental health?*

3.2.1 Summary information on included studies

Table 3-4 presents studies in alphabetical order. This order will be used in subsequent tables to indicate the studies that are being discussed. These 19 articles were coded for study focus, study keywords, participant and institution descriptions, journal discipline, type of engineering graduate student population analyzed, study type, methods used, and work referenced (theories and cited work). The years of publication for included studies ranged from 2001 to 2019. Table 3-5 includes descriptive statics on information reported for each study (i.e., study type, methods, participants' degree of study, and theories/cited work).

3.2.1.1 Study foci and keywords

The article's foci or goals were coded from the stated research question(s) and purposes of the studies. Some articles also explicitly stated the goals of the study. The foci and goals were then used to generate keywords, as detailed in Table 3-4, with the most cited across the 19 studies being citizenship/nationality (7), race/ethnicity (6), gender/sex (5), and well-being (5). I intentionally generated keywords based on reading the article rather than using the keywords provided by each article. The generated keywords were used to get a sense of the research being conducted.

3.2.1.2 Participants and institutions

Participant data as reported in each study can be found in Table 3-4, which is categorized by graduate degree program in Table 3-5. Seven articles did not specify the degree type among graduate students, whereas five indicated both master's and doctoral students and six indicated only doctoral students. Two included postdoctoral researchers. Institutional data for each study is detailed in Table 3-4. Some articles provided the institution name(s), while others only described them (e.g., “a large public research university”).

Table 3-4. Summary information for the 19 studies, including focus, information on participants and institution, keywords, discipline, and whether engineering graduated (Eng. Grad.) students were pulled out specifically in the study.

Study		Focus	Participants and institutions	Keywords	Journal discipline	Pull out Eng. Grad. Students
1	Amon (2017)	STEM women's career trajectories/experiences in STEM leadership positions	46 graduate students and postdoctoral fellows (STEM) from a large public research university	Career, Gender/Sex, Leadership, Stereotypes	Psychology	No
2	Burt, Williams, & Smith (2018)	Role strain for Black male students, focus on ecological and sociological barriers	21 graduate students from a Midwestern University	Coping, Gender/Sex, Isolation, Microaggressions, Persistence, Race/Ethnicity, Racial Fatigue, Role Strain, Structural Racism & Barriers, Well-Being	Education	Yes (quotes)
3	Carter-Veale, Tull, Rutledge, & Joseph (2016)	The effectiveness of a Dissertation House program to increase retention and PhD completion	Study 1: 1,304 doctoral students (451 current) Study 2: 267 doctoral students Participants from three University of Maryland campuses (College Park, Baltimore, and Baltimore County)	Community, Degree Completion, Dissertation Writing, Social Support	Education	No
4	Cross (2001)	Role of gender on performance and ability in grad school; Relationship between perceptions of environment and self-evaluations of stress and self-esteem	101 graduate students from Colleges of Engineering and Natural Sciences at a large Southwestern University	Academic Environment, Gender/Sex, Self Esteem, Stress	Psychology (Applied)	No
5	Delaine & Fontecchio (2009)	The use of an online social platform (Facebook) to create a support space for minorities in STEM	Graduate students in the Philadelphia Bridge to the Doctorate program which includes students from Drexel University, Delaware State, Temple University, and University of Delaware	Collective Knowledge, Online Social Platforms, Race/Ethnicity, Underrepresented Minorities	Engineering Education Research	No
6	Fisher et al. (2019)	Relationship departmental structure and belonging, look across race and gender	283 graduate students; 114 from UC Berkeley, 110 from UCLA, 125 students Stanford, and 150 from Caltech	Gender/Sex, Program Structure, Race/Ethnicity, Sense of Belonging, Underrepresented Minorities, Well-Being	Science and Medicine	No

Study		Focus	Participants and Institutions	Keywords	Journal Discipline	Pull out Eng. Grad. Students
7	Hyun, Quinn, Madon, & Lustig (2007)	International graduate students' mental health needs, knowledge of services, and factors influencing help-seeking behavior	3,121 graduate students from a large Western University	Citizenship/Nationality, Help-Seeking, Resource Knowledge & Utilization, Well-Being	College Health	No
8	Li & Stodolska (2006)	The interplay of translational status and leisure experience for Chinese international graduate students	16 graduate students enrolled at the University of Illinois at Urbana-Champaign	Citizenship/Nationality, Leisure, Transnational Experiences, Well-Being	Leisure	Yes (quotes)
9	Liao & Wei (2014)	Interplay of cultural values, psychological variables, experiences, and psychological outcome for Chinese international students	370 (188 graduate) students from two Midwest institutions, one West Coast and one East Coast	Academic Confidence, Citizenship/Nationality, Cultural Values, Familial Recognition, Self-Worth	Psychology (Applied)	No
10	Lipson et al. (2016)	Variations in student mental health and help-seeking across academic disciplines	15,852 graduate students (9,872 master's 5,980 doctoral) from 81 U.S. Institutions, most 4-year (94.9%)	Help-Seeking, Resource Utilization	College Mental Health	Yes (data table, data points)
11	Lubinski, Benbow, Webb, & Bleske-Rechek (2006)	The SAT captures information more than book-learning potential that can be used to track human capital	547 graduate students, institutions not given	Career Life Satisfaction, Predicting Occupational Success	Psychology	No
12	McGee & Bentley (2017)	Effect of racialization on experiences and well-being of Black women in STEM	3 (2 doctoral) students, one from a Southern HWI and one from a Southern HBCU	Gender/Sex, Race/Ethnicity, Race-Gender Bias, Structural Racism & Sexism	Learning Science and Education	Yes (quotes)
13	McGee, Griffith, & Houston (2019)	Black student experiences related to stress, strain, and the associated coping habits	48 doctoral students from ten different institutions, 9 of which are from HBCUs	Academic Performance Anxiety, Coping, Race/Ethnicity, Racial Battle Fatigue, Role Strain, Strain, Stress	Education	Yes (quotes)
14	Mikal, Yang, & Lewis (2015)	Use of internet to establish a support network for Chinese international students	8 graduate students (3 master's, 5 doctoral), 1 postdoc from a major Public University in California	Citizenship/Nationality, Collective Knowledge, Coping, Help-Seeking, Internet Usage, Social Support	Education	Yes (quotes)

Study		Focus	Participants and Institutions	Keywords	Journal Discipline	Pull out Eng. Grad. Students
15	Posselt (2018)	Factors influencing doctoral student persistence and well-being, defining a framework for holistic faculty support	29 doctoral students from two well-known research universities in two different regions of the United States	Persistence, Social Support, Validation, Well-Being	Education	Yes (quotes)
16	Rice et al. (2009)	International graduate students advising experience, look across gender or major area of study	358 graduate (53 master's and 305 doctoral) students from the University of Florida (Gainesville, FL)	Advising Relationship, Citizenship/Nationality	Psychology (Applied)	Yes (data table, data points)
17	Rice, Choi, Zhang, Morero, & Anderson (2012)	Comparing sources of stress and mental health of Chinese and Asian Indian students	295 (72% engineering) graduate students from a major U.S. university	Academic Pressure, Acculturative Stress, Citizenship/Nationality, Depression, Self-Critical Perfectionism	Psychology (Applied)	No
18	Torres, Driscoll, & Burrow (2010)	Obstacles overcome during doctoral studies and influence on mental health	Study 1: 97 African American students enrolled in universities across the state of Florida Study 2: 174 (120 current) African American doctoral students, students enrolled in over 45 different colleges and universities, most HWIs (92.4%), some predominantly African American institutions (5.7%), and some neither (1.9%)	Coping, Depression, Isolation, Race/Ethnicity, Racial Discrimination & Microaggressions, Stress	Psychology (Applied)	No
19	Zhou (2014)	Challenges faced by Chinese international students, motivation to persist and influence of cultural factors	6 doctoral students from American Northeastern University, a midsized Public Research University.	Advising Relationship, Citizenship/Nationality, Loneliness, Motivations to Persist, Program Dissatisfaction	Education	Yes (quotes)

*Note: HWI = historically White institution; HBCU = historically Black colleges and universities

Table 3-5. Descriptive statistics on included studies type, methods, participants' degree of study, and theories/cited work

Study Information	Number of Studies	(%)	Specific Studies 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Type of study																					
Observational	18	(95)	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Intervention	1	(5)			x																
Methods																					
Qualitative	12	(63)	x	x	x		x			x				x	x	x	x	x		x	x
Document analysis	2	(11)	x				x														
Interviews	8	(42)	x	x						x				x	x	x	x				x
Observations	0	(0)																			
Surveys	3	(16)			x													x		x	
Quantitative	10	(53)			x	x		x	x		x	x	x					x	x	x	
Descriptive statistics	9	(47)			x	x			x		x	x	x					x	x	x	
Inferential statistics	10	(53)			x	x		x	x		x	x	x					x	x	x	
Hypothesis testing	1	(5)			x																
Modeling	3	(16)						x										x		x	
Mixed methods (Both)	3	(16)			x													x		x	
Participants																					
Doctoral	6	(32)			x			x						x	x		x				x
Master's and doctoral (mixed)	5	(26)							x			x				x		x	x		
Graduate (degree not specified)	7	(37)	x	x		x				x	x		x							x	
Post doctorates	2	(11)	x													x					
Theories/Cited work	14	(74)																			
Referenced theory(s)/concept(s)	7	(37)			x	x		x		x				x	x						x
Model(s) or framework(s)	10	(53)	x	x	x						x			x	x		x	x	x	x	
Mental health survey questions	12	(63)																			
Generated own questions	9	(47)			x	x		x	x	x		x	x	x				x			
Used existing questionnaires	6	(32)				x					x	x						x	x	x	

3.2.1.3 Journal discipline

The 19 studies that met the study criteria came from 19 different journals. Journal disciplines included college health/college mental health (2), education (8), leisure (1), psychology/applied psychology (7), and science and medicine (1). These publications featured areas of allied health (health care professional) literature, biomedical science, behavioral science, education, health sciences, life sciences, mental health, nursing, physical sciences, psychology, public health, and social sciences.

3.2.1.4 Singling out of engineering graduate students

Engineering disciplines were determined using descriptive categories provided by the National Science Foundation (National Science Foundation National Center for Science and Engineering Statistics, 2013). Of the 19 studies included in this review, only nine singled out engineering graduate students in their analyses. Seven studies did so with qualitative evidence via quotes. Two studies did so with quantitative evidence, one via a table and the other by simply providing a descriptive statistic.

3.2.1.5 Type of study and methods used

All but one of the articles were observational studies that were closely split between quantitative (10) and qualitative (12) studies. Three of the studies used both methods. Quantitative methodologies were coded to classify the use of descriptive statistics (e.g., mean, median, mode), inferential statistics (i.e., anything with a p-value, including t-tests, regression analysis), hypothesis testing (e.g., an intervention comparing groups), and modeling (e.g., factor analysis and path modeling). Inferential statistics (10) and descriptive statistics (9) were most common, whereas modeling (3) and hypothesis testing (1) were less common. In terms of qualitative methodologies, I coded for document analysis (e.g., photographs, collected materials, artifacts), interviews (e.g., one-on-one questioning, focus groups, case studies), observations (e.g., watching in natural environments), and surveys (i.e., open-ended questions). Interviews (8) were the most common, followed by surveys (3) and document analysis (2). Observations were not conducted or included in any of the studies.

3.2.1.6 Work referenced

Due to the articles' different writing styles and journal homes, I decided to be less stringent about what was included when coding this section. That is, any theory, concept, framework, or model that was mentioned was included here. Relevant theories and concepts were more likely to be found in the introduction, background, and motivation sections, whereas relevant models and frameworks were likely discussed in the methods and results sections. Theories and concepts were used as references to ground and motivate the research, whereas models and frameworks were used to guide the methodology and subsequent analysis. These were coded for separately.

A total of 13 different concepts or theories were cited across seven articles. Racial battle fatigue (W. A. Smith, 2004; W. A. Smith et al., 2011) was the only theory/concept cited multiple times (twice). This was defined as “a response to the distressing mental/emotional conditions that result from facing racism daily” (W. A. Smith, 2004, p. 180) that can cause debilitating psychological and physiological stress (McGee et al., 2019; McGee & Bentley, 2017). There were 16 different models or frameworks cited across 10 articles. Grounded theory (Corbin & Strauss, 2008; Glaser, 1998; Glaser & Strauss, 1967a; Strauss & Corbin, 1990) was cited in four studies (Amon, 2017; Burt et al., 2018; Rice et al., 2009; Torres et al., 2010), generally as a methodological approach to the study design or analysis. The acculturation framework/model (Berry et al., 1987) was cited twice (Liao & Wei, 2014; Rice et al., 2012). This framework/model is used to discuss assimilation to unfamiliar cultures. It was used to help depict the process from acculturation experiences in the academic setting to adaptation, measured through mental health outcomes. All other concepts, theories, models, and/or frameworks were cited in only one article.

3.2.2 Demographic information

Of the demographics coded for detailed in Table 3-6, four were reported in at least half of the articles: gender/sex (18), academic discipline (15), age (12), and year in the program (11). Academic disciplines were coded by mapping disciplines to the National Science Foundation's classification of engineering fields of study (National Science Foundation National Center for Science and Engineering Statistics, 2013). Seven unique disciplines were reported across eight articles. Of these, electrical, electronics, and communications engineering was cited the most in six articles, followed by civil engineering, materials science engineering, and mechanical engineering, each being cited in four articles. This was followed by chemical engineering and industrial and manufacturing engineering, each being cited in three articles, with aerospace, aeronautical, and astronomical engineering being cited in only two articles. Four articles reported disciplines NSF reports as “OTHER,” and 10 articles did not report specific disciplines. Participants' citizenship/nationality was reported at the same frequency as race/ethnicity (9), with relationship status (6), and parents' education (3) being reported less frequently. Finally, the participants' living situation was not directly reported in any of the studies, but one study asked about roommates. The first reviewer coded all responses to determine if any patterns appeared across studies that may have been missed. Anything reported in more than one study was included. Five additional pieces of information were coded for financial support/income (2), sexual orientation (2), institutional information (4), children/dependent status (5), and time in the United States/length of stay (6).

Table 3-6. Demographic information presented for participants in the included studies.

Demographics	Number of studies (%)	Specific studies 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Academic discipline	15 (79)	x	x		x		x		x	x	x	x	x	x	x	x	x	x		x
Aerospace, aeronautical, and astronomical	2 (11)		x											x						
Chemical	3 (16)		x											x			x			
Civil	4 (21)		x											x		x	x			
Electrical, electronics, and communications	6 (32)		x						x					x	x		x			x
Industrial and manufacturing	3 (16)		x											x			x			
Materials science	4 (21)		x											x					x	x
Mechanical	4 (21)		x						x				x	x						
Other																				
Agricultural	1 (5)																x			
Bioengineering and biomedical	2 (11)		x											x						
Computer	2 (11)												x	x						
Environmental health	1 (5)													x						
Engineering, other	1 (5)		x																	
Engineering program not specified	10 (53)	x		x	x	x	x	x		x	x	x						x		
Age	12 (63)	x					x	x	x	x	x	x			x		x	x	x	x
Citizenship/Nationality	9 (47)	x		x			x			x	x				x		x	x		x
Gender/Sex	18 (95)	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
Parent's education	3 (16)		x								x		x							
Living situation	1 (5)														x					
Race/Ethnicity	9 (47)	x	x	x			x	x			x		x	x		x			x	
Relationship status	6 (32)							x		x		x						x	x	x
Year in program	11 (58)		x		x		x	x					x	x		x	x	x	x	x
Other	16 (84)	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	
Children/Dependents	5 (26)						x	x				x							x	x
Financial support/income	2 (11)											x					x			
Institutional information	4 (21)		x				x							x					x	
Sexual orientation	2 (11)						x	x												
Time in US/length of stay	6 (32)			x					x	x					x		x	x		

3.2.3 Academic outcomes

I coded 10 academic outcomes, as detailed in Table 3-7. Table 3-8 presents the main uses and findings of each of these academic outcomes by study. Four studies did not include any academic outcomes (Amon, 2017; Delaine & Fontecchio, 2009; Hyun et al., 2007; McGee et al., 2019). From the other 15 studies, grade point average (GPA) was cited the most (7), followed by English language (5), and graduate record examination (GRE) test scores (4). GPA and GRE test scores were cited to benchmark students' academic achievements or to compare groups. English language was discussed in every study, specifically English proficiency being a factor in international students' educational experiences (e.g., difficult social interactions or increased acculturative stress levels). Several academic outcomes were found in only two studies: attrition/retention, post-graduation career intentions, publication rate, and time to degree completion. Attrition and retention were used to assess an intervention's success (along with graduation rate and time to degree) and provide insight into a potential consequence from a misalignment in graduate school expectations for international students. Similarly, career intentions post-graduation indicated how students' experiences altered their intended career paths (e.g., from academia to industry). Publication rate was used to assess research progress and to explore racial/ethnic variation in publication rate. Time to degree was also used as a covariate in analysis. Graduation rate, patent records, and time with advisor were each coded for in one study. Time with advisor was used to examine that relationship whereas patent records were used to assess career success.

Table 3-7. Academic outcomes presented in the included studies.

Academic outcome	Number of studies (%)		Specific studies																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Attrition/Retention	2	(11)			x																x
English language	5	(26)								x	x					x			x		x
Grade point average (GPA; past & current)	7	(37)		x		x					x	x		x			x	x			
Graduation rate	1	(5)			x																
GRE test score(s)	4	(21)				x		x					x				x				
Patent record	1	(5)											x								
Post-Grad career intentions	2	(11)		x										x							
Publication rate	2	(11)						x													x
Time with advisor	1	(5)																x			
Time to degree completion	2	(11)			x			x													

Table 3-8. Specifics on academic outcomes presented in the included studies.

Academic outcome and main use / findings (number of studies; %)	Study cited
Attrition or retention (2; 11%)	
intervention increased retention by 64% (96% compared to 67%)	3; Carter-Veale et al. (2016)
misalignment in expectations (e.g., advisor, U.S. tenure-job market, faculty life) alluded to harm retention	19; Zhou (2014)
English language (5; 26%)	
English was a barrier; preferred leisure activities with those from the same ethnic background and who spoke Chinese	8; Li & Stodolska (2006)
English was a barrier; English proficiency (in writing, reading, listening, speaking, & overall) correlated negatively with acculturative stress	9; Liao & Wei (2014)
English language & culture were barriers in forming friendships	14; Mikal et al. (2015)
English was a barrier; higher levels of acculturation stress & lower levels English competency/cultural awareness in Chinese students	17; Rice et al. (2012)
English was a barrier	19; Zhou (2014)
GPA (past & current) (7; 37%)	
provide context of the strong academic backgrounds	2; Burt et al. (2018)
compared women and men's academic performance, finding no statistical difference in their previous or current performance	4; Cross (2001)
correlation analysis on GPA and other metrics against psychological effects, finding no statistically significant correlation	9; Liao & Wei (2014)
weigh response data for quantitative analysis	10; Lipson et al. (2016)
criterion for including participants in the study	12; McGee & Bentley (2017)
students felt supported when advisors looked at a poor GPA or course performance as a metric of short-term ability vs. long-term capabilities	15; Posselt (2018)
more likely to report higher levels of rapport and satisfaction with advisors if doing well academically	16; Rice et al. (2009)
Graduation rate (1; 5%)	
program increased likelihood of graduation by 92%; 76% graduated in program compared to 42% not	3; Carter-Veale et al. (2016)
GRE test score(s) (4; 21%)	
compared women and men's academic performance, finding no statistical difference	4; Cross (2001)
covariate for quantitative analysis	6; Fisher et al. (2019)
inclusion criterion for study participants	11; Lubinski et al. (2006)
validate feelings of self-doubt and not belonging in their program; advisors' responses helped combat doubts and support their well-being	15; Posselt (2018)
Patent record (1; 5%)	
Proxy for career success; higher rate than general public	11; Lubinski et al. (2006)
Post-Grad career intentions (2; 11%)	
presented as part of participant profile	2; Burt et al. (2018)
Experiences changed career paths (i.e., workshop encouraging students of color pursue faculty positions vs. sexual assault, racial/gender stereotyping)	12; McGee & Bentley (2017)
Publication rate (2; 11%)	
Black students ~3x less likely published in an academic journal; mediated by perceived readiness, sense of belonging, & thoughts on program structure; students with higher perception of success more likely publish	6; Fisher et al. (2019)
Proxy for research productivity; students unhappy with progress and advisor	19; Zhou (2014)
Time with advisor (1; 5%)	
Longer in program, less likely to identify with advisor or seek guidance; those not satisfied would intentionally increase separation	16; Rice et al. (2009)
Time to degree completion (2; 11%)	
funding model motivated quicker completion of dissertation & degree	3; Carter-Veale et al. (2016)
co-variate for quantitative analysis	6; Fisher et al. (2019)

3.2.4 Mental health measures and instruments

3.2.4.1 Mental health instruments cited

Only survey questions or items that directly related to mental health measures were included. Although demographic questions can relate to mental health measures, such as relationship status, they tended to be more general and were therefore omitted. As detailed in Table 3-5, 12 of the studies included surveys with mental health related questions. Nine of those studies had questions the researchers created specific to their study and six studies used existing questionnaires. Three studies included both existing questionnaires and created their own questions. Table 3-9 details the cited mental health questionnaires used across these six studies, the topics covered, the number of questions asked, and the citation for the survey instrument. From these instruments, 15 unique surveys were cited. The Perceived Stress Scale (Cohen et al., 1983; Cohen & Williamson, 1988) was used in two of the six studies, and the Center for Epidemiological Studies–Depression scale was used in both its full form in one study and short form in another study (Cole et al., 2004; Radloff, 1977). Depression and perceived stress were the topics of two of the surveys; topics appearing only once include academic stress, acculturative stress, advising experiences, advising relationships, psychosocial competence, engagement with environment, familial values, generalized anxiety disorder, impact of racial microaggressions, perfectionism, self-esteem, and self-worth. These topics were also measures directly coded for or included as main findings of the paper.

3.2.4.2 Mental health measures

There were 13 major mental health measures across the 19 studies, as detailed in Table 3-10. Relationship(s) were cited in 13 studies, with peers being cited the most frequently (11), followed by an advisor (9), friend(s) (6), family (4), spouse or significant other (2), and

Table 3-9. Mental health related survey instruments cited in the included studies.

Survey instrument name	Mental health topic; Number of items	Survey citation
Academic Competence subscale from Contingencies of Self-Worth Scale	Extent to which one bases self-worth on academic achievement; 5-items	(Crocker et al., 2003)
Advisory Working Alliance Inventory	Three dimensions of advising relationships (rapport, identification–individuation, and apprenticeship); 30-items	(Schlosser & Gelso, 2001)
Almost Perfect Scale–Revised	Self-critical perfectionism; 12-items	(Slaney et al., 2001, 2002)
Behavioral Attributes of Psychosocial Competence Condensed Form	Psychosocial competence culturally specific to the mainstream United States; 13-items	(Zea et al., 1996)
Center for Epidemiological Studies–Depression scale (CES-D) and CES-D Short Form	Full: assesses participants' severity of depressive symptoms at both measurement occasions; has been used extensively with ethnic minority samples; 20-items Short Form: assess depressive symptoms during the past week; 10-items	Full: (Radloff, 1977) Short Form: (Cole et al., 2004; Radloff, 1977)
Daily Life Experience-Frequency Scale (DLE-FS), subscale of the Racism and Life Experience scale	Assesses the frequency and impact of experiencing 20 racial microaggressions; 20-items	(Harrell, 1994)
Family recognition through achievement (FRTA) subscale from Asian Values Scale-Multidimensional (AAVS-M)	Level of adherence to the value of bringing honor to one's family by achieving academically and doing well occupationally; 14-items	(Kim et al., 2005)
Generalized Anxiety Disorder 7-item (GAD-7)	Measures symptoms of generalized anxiety disorder; 7-items	(Spitzer et al., 2006)
Inventory of College Challenges for Ethnic Minority Students (ICCEMS)	Academic stress due to struggles with academic challenges and difficulties in expressing oneself in academic settings; 5-items	(Ying et al., 2004)
Patient Health Questionnaire-9 (PHQ-9)	Nine core symptoms of a major depressive episode and measures anxiety (panic and generalized anxiety disorder); 9-items	(Spitzer et al., 1999)
Perceived Stress Scale (PSS)	Subjective global stress, assesses individuals' appraisal of their lives as unpredictable, uncontrollable, and overloaded; 10-items	(Cohen et al., 1983; Cohen & Williamson, 1988)
Positive Affect subscale from the Positive and Negative Affect Schedule Scale (PANAS)	Experiences of pleasurable engagement with the environment; 10-items	(Watson et al., 1988)
Self-Esteem Scale	Self-esteem; 10-items	(Rosenberg, 1965)
Societal, Attitudinal, Familial, and Environmental Acculturative Stress Scale–Short Form (SAFE)	Acculturative stress in social, attitudinal, familial, and environmental contexts; 24-items	(Mena et al., 1987)
Survey on Doctoral Education and Career Preparation	aspects of the advising experience; 8-items	(Golde & Dore, 2001)

Table 3-10. Mental health measures discussed in the included studies.

Variables	Number of studies	(%)	Specific Studies 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Anxiety	4	(21)										x			x	x	x				
Coping habits	7	(37)		x			x			x				x	x		x			x	
Depression	5	(26)						x				x			x				x	x	
Emotion(s)	11	(58)	x	x	x		x	x	x		x			x		x	x				x
Existing mental health problem	2	(11)							x			x									
Life satisfaction	4	(21)	x							x			x								x
Relationship(s)	13	(68)	x	x	x		x	x	x				x	x	x	x	x	x			x
Family	4	(21)	x						x							x					x
Friends	6	(32)	x	x			x		x							x					x
Roommates	1	(5)														x					
Spouse/Significant other	2	(11)							x				x								
Advisor	9	(47)	x	x	x				x					x	x		x	x			x
Peers	11	(58)	x	x	x		x	x	x					x	x	x	x				x
Self-Harm	1	(5)										x									
Non-life-threatening	1	(5)										x									
Suicidal	0	0																			
Suicidal ideation	1	(5)										x									
Stress	11	(58)			x	x		x	x		x			x	x	x			x	x	x
Treatment utilization	1	(5)										x			x						
Well-being	5	(26)		x		x		x							x	x					x
Work-life balance	6	(32)	x		x					x			x		x	x					
Other	12	(63)	x	x	x	x		x			x			x	x		x		x	x	x
Gender stereotypes/sexism	4	(21)	x	x										x	x						
Motivation to persist	2	(11)													x						x
Perceptions of environment	2	(11)				x		x													
Perceptions of self/self-esteem	3	(16)				x		x			x										
Racial stereotyping/role strain	5	(26)		x										x	x		x			x	
Self-critical/imposter syndrome	2	(11)													x				x		
Social support/sense of belonging	11	(58)	x	x	x		x	x			x			x	x	x	x			x	

roommates (1). Emotion(s) and stress were both cited in 11 studies, with emotions coded for anything regarding feelings or affective states (e.g., happy, sad, angry, etc.). Coping habits were cited in seven studies and work-life balance in six. Depression and well-being were both cited in five studies, whereas anxiety and life satisfaction were cited in four. Existing mental health problem(s) were cited in two studies. Treatment utilization, non-life-threatening self-harm, and suicidal ideation were each cited in one study. Fourteen of the 19 studies included some other mental health measure. As with the demographic measures, the first reviewer coded all responses to determine if any patterns may have been missed, identifying seven additional measures mentioned more than once, across 12 studies. Social support and/or sense of belonging were cited the most across 11 of the studies. This was followed by racial stereotyping/role strain (5), gender stereotypes and/or sexism (3), and perceptions of self and/or self-esteem (3). Motivation to persist, perceptions of the environment, self-criticism, and/or imposter syndrome were each reported in two studies.

3.2.5 Mental health findings

After the mental health measures were coded, each study's main mental health findings were synthesized. The main findings for each study were grouped into five categories: social support and sense of belonging; student–advisor relationship; cultural barriers faced by international students; gender and racial stereotypes; and generalized findings. A short write-up of these findings by category and study appears in Appendix A (Table A-1).

3.2.5.1 Social support and sense of belonging

Social supports and sense of belonging were discussed in 11 studies (Amon, 2017; Burt et al., 2018; Carter-Veale et al., 2016; Delaine & Fontecchio, 2009; Fisher et al., 2019; Liao & Wei, 2014; McGee et al., 2019; McGee & Bentley, 2017; Mikal et al., 2015; Posselt, 2018; Torres et al., 2010). In general, students tended to seek out peers, lab mates, or postdocs for help (Posselt, 2018). Virtual platforms and in-person community building interventions helped build support systems (Carter-Veale et al., 2016; Delaine & Fontecchio, 2009). Chinese international students discussed the need for culturally appropriate social-emotional supports (i.e., talking with friends and family), emphasizing their hesitancy to discuss mental health related topics with others (Liao & Wei, 2014; Mikal et al., 2015). Black students often felt that they were unwanted in engineering communities; these students commented on the lack of supports available to them compared to their peers due to the low numbers of racially/ethnically minoritized students and faculty of color in academia (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). This is concerning as other studies found that feeling accepted empowered students and increased their reported well-being (Amon, 2017; Fisher et al., 2019).

3.2.5.2 Student–advisor relationship

The student–advisor relationship was discussed in nine studies (Amon, 2017; Burt et al., 2018; Carter-Veale et al., 2016; Hyun et al., 2007; McGee et al., 2019; McGee & Bentley, 2017; Posselt, 2018; Rice et al., 2009; Zhou, 2014). Good advising experiences provided opportunities to build trust in the relationship, which helped students visualize their future careers (Amon, 2017; Hyun et al., 2007). However, students perceived going to faculty for support as a last resort, fearing faculty would treat them differently (Posselt, 2018). Students dissatisfied with their advisors attributed this to misalignment in research interests, advising/communication styles, expected work-life balance, anticipated financial support, and expected encouragement (Burt et al., 2018; Carter-Veale et al., 2016; McGee et al., 2019; McGee & Bentley, 2017; Rice et al., 2009; Zhou, 2014).

3.2.5.3 Cultural barriers international students confronted

The cultural barriers international students confronted during their graduate school experiences were discussed in six of the studies. Students discussed acculturative stress (i.e., stressors in assimilating to a new culture; Hyun et al., 2007; Li & Stodolska, 2006; Liao & Wei, 2014; Mikal et al., 2015; Rice et al., 2012; Zhou, 2014). International students' reports on their mental health problems on par with domestic student rates; common stressors included acculturative stress, financial problems, basing self-worth on academic competence, and being self-critical (Hyun et al., 2007; Li & Stodolska, 2006; Liao & Wei, 2014; Rice et al., 2012). Chinese graduate students were also less likely to know about or access mental health resources compared to domestic students (Hyun et al., 2007; Mikal et al., 2015). Filial piety, or the respect for the burden borne by one's parents, elders, and ancestors and awareness of the obligation to repay the debt, drove individual conduct by influencing students' intentions to persist. Students experienced fear and shame at the thought of leaving their programs from the high social cost of quitting and desire to bring honor to their family via scholastic achievement (Liao & Wei, 2014; Mikal et al., 2015; Rice et al., 2012; Zhou, 2014).

3.2.5.4 Gender and racial stereotypes

Six of the studies examined gender and racial stereotypes (Amon, 2017; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Posselt, 2018; Torres et al., 2010). Minoritized students in engineering faced additional barriers in their studies, from assumptions of intellectually inferiority to discrimination; persisting in these environments required additional energy and coping strategies at the cost of their physical and mental health (Amon, 2017; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). Having faculty with shared identities helped students come forward with experiences of sexual assault or harassment (Posselt, 2018).

3.2.5.5 Generalized findings

Four studies focused on generalized findings related to asking for help and levels of distress (Cross, 2001; Fisher et al., 2019; Lipson et al., 2016; Lubinski et al., 2006). Overall, engineering graduate students are less likely to ask for help concerning mental health problems despite over 25% of students meeting the criteria for self-reported mental health problems (Lipson et al., 2016). Although there were no differences in academic performance, women had higher levels of distress, perhaps due to their lower self-evaluations of intelligence (Cross, 2001; Fisher et al., 2019; Lubinski et al., 2006).

3.3 Study Limitations

As with any review, this one has limitations. It is possible that our choice of databases or the questions used to guide the review process eliminated relevant studies. Future researchers should examine alternate study selection approaches, such as using automated text analysis or other natural language processing tools that can automate searching in the screening process, reduce human error, and access more databases. Furthermore, this ScLR does not include any measure or rating of how well the topic of engineering graduate students' mental health is discussed. This limits recommendations that can be inferred from this study (Joanna Briggs Institute, 2015). Future research might also include information presented by renowned mental health organizations, which appear on online platforms, editorials, briefs, and more.

The findings presented here are not intended as an exhaustive list of what should be considered in terms of demographics, academic outcomes, or mental health outcomes for engineering graduate students' mental health (e.g., I did not code for financial concerns). These findings are simply a collection and synthesis of the work that has been done as of this writing. Additionally, the exclusion criteria may have excluded studies important to engineering graduate student mental health that should be considered in future reviews. Subsequently, there is a clear need for more research.

3.4 Discussion

This study aims to answer the research question: *What is the current landscape of literature about engineering graduate students' mental health?* This research question guided the formation of the inclusion criteria, which in turn formed the screening questions. These screening questions determined study eligibility, resulting in selection of 19 studies. This study's stringent requirements for inclusion (e.g., a U.S. student population, peer-reviewed sources, explicitly naming engineering graduate students) may explain this small number. Nevertheless, information collected from these papers is insightful. The main findings of this ScLR were grouped into five areas: social support and sense of community, advisor relationship, cultural barriers, gender and racial stereotyping, and generalized findings. The following sections presents an interpretation of the findings in three main themes: research about engineering graduate student mental health is limited and varies greatly, the importance of graduate students' advising relationships and social supports, and more work is needed to explore the racialized, gendered, and intersectional experiences of various engineering graduate student populations.

3.4.1 Engineering Graduate Students' Mental Health Research is Limited and Varies Greatly

Searching across five databases produced only 19 papers that met the inclusion criteria. None were published in the same journal, and only one of them was an engineering-specific source (*American Society for Engineering Education [ASEE] Annual Conference and Exposition*

Proceedings) although several engineering education journals exist (e.g., *Global Journal of Engineering Education*; *International Journal of Engineering Education*) and ASEE being sourced in Scopus' database (American Society for Engineering Education (ASEE), 2021; Scopus, 2021). Unsurprisingly, research designs varied across the reviewed studies. First, five were part of larger studies that examined both undergraduate and graduate student populations, and two combined graduate students with postdoctoral researchers. Seven of the studies did not distinguish between master's, doctoral, or joint master's-doctoral degree students, suggesting interest in determining differences according to program and level is limited. Only nine of the studies specifically examined engineering graduate students' experiences in the findings (seven through quotes, two through data points) with only one study focused on only engineering graduate students. The remaining 10 studies made generalized claims concerning the entire study population, not specifying specific engineering disciplines, and often including multiple academic disciplines.

Both qualitative and quantitative research methods are vital and needed to understand engineering graduate students' mental health experiences. Nine studies used qualitative methods, seven used quantitative methods, and three of them used mixed methods. In engineering education research, quantitative studies provide generalizability to a larger sample through representative sampling, whereas qualitative studies support transferability, or the application of the findings to other settings, through rich descriptions (Borrego et al., 2009). Mixed methodologies try to find a balance of these two methods to best answer the research question(s) at hand. The differing research methodologies across the reviewed studies is not as surprising given the variation in research foci (coded as study keywords in Table 3-4). With ten major keywords, studies focused on academic performance anxiety, acculturative stress, predicting occupational success, self-critical perfectionism, and more. There was also variation in the theories and frameworks used to ground and motivate these works. Only seven of the 19 studies cited a theory or concept to ground and situate the work, whereas 10 studies included a model or framework that researchers used to guide the methodology or analysis. Although using past work to motivate studies and inform research designs is promising, it is intriguing that only three of these theories or concepts were cited multiple times (racial battle fatigue, grounded theory, and the acculturation framework/model).

The demographic information coded across studies also varied. Many studies were designed to explore differences in demographic groups (e.g., gender/sex). However, over one third of the studies did not report basic demographic information (e.g., citizenship/nationality, age). Data pertinent to well-being (e.g., living situation or parent's education level) were found in no more than two of the studies or not present at all. For instance, no study included academic milestones or on-campus resource utilization. Milestones are inherent to graduate school (e.g., candidacy, dissertation, defense, etc.) and academic resources such as writing centers may provide supports to help graduate students progress in their academic careers (Kaler & Stebleton, 2019; Owens et al., 2020). Furthermore, studies had limited discussion of the impact of finances on engineering graduate students' mental health. Coming from a lower socioeconomic background can be a risk factor for depression and anxiety; additionally, a student's economic background can also impact their sense of belonging (Ostrove et al., 2011; Ridley et al., 2020).

Although several academic measures were included, none were found in more than seven studies. Those found in only one study include graduation rate, patent record, and time with advisor. Although patent record may be a more targeted outcome, graduation rate and time with one's advisor are common metrics when discussing the state of graduate education. Time with one's advisor might also be considered as time to degree completion; however, this was only cited twice. On the other hand, GPA, GRE scores, and proficiency with English language were the most frequently reported academic outcomes in this review. This is unsurprising as these are all metrics used in U.S. admission processes and, therefore, can be used to uniformly discuss graduate students' academic outcomes.

The mental health factors included in the studies was also surprising. Although some were cited multiple times (advisor relationship(s), emotion(s), relationships with peers, and stress), several factors were only cited once (relationships with roommates, self-harm, and treatment utilization). Most alarming is that only one study reported on treatment utilization and self-harm - and no study reported on help-seeking behaviors or suicidal ideation/attempts. Engineering students are much less likely to seek help than students in other disciplines, and not seeking help can negatively impacts one's personal and professional well-being (Lipson et al., 2016). As stated earlier, delayed help-seeking can affect treatment access and efficacy as well as lead to more severe mental health problems (Hunt & Eisenberg, 2010; Lipson et al., 2016). Given that death by suicide is the second leading cause of death in college-aged individuals and that suicidal ideation has almost doubled in the past decade, suicide and related forms of self-harm need to be studied in this population (Lipson, Lattie, et al., 2019; J. C. Turner et al., 2013).

I identified two main concerns regarding the mental health survey instruments used. First, these instruments were published from 1965 to 2006, bringing into question the applicability of these surveys. For example, many mental health instruments do not include experiences of racism in mental health diagnosis, which can be a significant factor for self-reported mental health outcomes for African American students (Chao & Green, 2011). Second, not every study provided the exact wording for each question. Only six studies used existing questionnaires, nine studies created their own, and seven studies did not provide any information on specific mental health items generated or surveys they may have cited. Because they did not provide this information in their methods or any other details on their survey instruments (e.g., length, phrasing, question order), they raise potential validity concerns and limit how other researchers can replicate or build upon these studies.

3.4.2 The Importance of the Advising Relationship and Social Supports

Relationships formed and leveraged during graduate school can have a strong impact on students' mental health and intentions to persist. When selecting a graduate school program, prospective students are frequently advised to seek out potential advisors who they feel they can have a strong positive relationship with (Gibbs et al., 2012; Luchini-Colbry, 2017). This is for good reason; advisors can greatly influence the graduate student experience, and difficulties in the advising relationship can lead to increased levels of depression and stress (C. M. Zhao et al., 2007). Unsurprisingly, the student-advisor relationship influenced many of the academic outcomes included in this review, including students' intentions to persist (i.e., attrition/retention), publication rates, and post-graduation career intentions. A positive experience with an advisor contributed to feelings of trust, support, and affirmed commitment to their work being (Amon, 2017; Posselt, 2018). In contrast, negative experiences resulted in reliance on other supports and coping strategies to continue their studies (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017). This may indicate the role of a faculty advisor and research context is more important for students' success than other measures. Recent work at an Australian university found that students' research environment, namely the research field and their advisor, had significant impact on academic outcomes (i.e., publications, citations, attrition rates), whereas a student's preparation (i.e., prior academic outcomes and research training) had minimal influence at most (Belavy et al., 2020). This once again highlights the importance of the advising relationship in a graduate student's academic career, and the importance of universities supporting both the students and advisors in this relationship, especially for minoritized individuals.

The lack of social supports for minoritized students in engineering within their lab, program, and school environments can make the relationship between student and advisor critical to student well-being (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017). One study in this review found almost a quarter of international students would change their advisor if they could (Rice et al., 2009). Engineering graduate students who identified as Black, women, international, and/or a combination of these identities persist in their programs despite the multitude of barriers they encountered. These experiences range from their advisor being inaccessible to being told that they were not capable of graduate work and therefore did not belong (Burt et al., 2018; McGee & Bentley, 2017; Torres et al., 2010). They faced a myriad of racial- and gender-based stereotyping that further tainted their relationships with their advisors. In addition to such discriminatory practices, misalignment in research interests, poor communication, and unrealistic expectations for a work-life balance could tarnish the advising relationship. These concerns were also echoed by graduate students considering their advisor a last resort for social or emotional support. Students' fears of being stigmatized, dismissed, or further discouraged made faculty an inaccessible resource for many (Posselt, 2018). Given these factors, students would often turn to emotionally draining, unhealthy coping strategies (e.g., self-preservation via intentional distancing from advisor) to function in hopes of still obtaining their degrees (Stallman et al., 2021). Although both students and advisors are responsible for the quality of their relationship, the inherent power imbalance and lack of required formal training on how to manage these relationships for both parties should not be overlooked.

Research has demonstrated that finding a community outside of the advising relationship can counteract negative graduate school experiences. The utility of social support and the need for a sense of community were salient themes found across studies. Whether these communities were formed online or in person, having a space to talk about graduate school life, concerns individuals were facing, feelings of isolation and doubt, and more helped students feel supported in their graduate studies (Amon, 2017; Delaine & Fontecchio, 2009; Mikal et al., 2015; Posselt, 2018). That is, the presence of social supports served as a mechanism to help students cope with their graduate school experiences and to persist. In one intervention, communities of all-but-dissertation doctoral students improved retention rates by 64% and likelihood of graduation by 92% (Carter-Veale et al., 2016). Similar interventions using cohort model approaches with professors and/or peers provide emotional support and a supportive environment (Bista & Cox, 2014). These supports were crucial to students' experiences and ability to cope with the stressors they faced. The most frequently reported mental health measures echoed this: emotion(s), relationships with peers, stress, and advisor relationship(s). Graduate students' mental health experiences largely depend on their environment and who they interact with. The relationships students form with their peers, advisor(s), faculty, and others are vital to the socialization process in transitioning to graduate school, where new students try to understand graduate school norms (e.g., navigating coursework, program environment, research, degree milestones, time commitment, etc.; Gardner & Barnes, 2007; Joseph, 2012; C. S. v. Turner & Thompson, 1993). As most students are adjusting to graduate school, it is not surprising that their personal and academic relationships are often tied to emotional responses and stress. Such relationships might provide social support or a source of stress and anxiety (Grady et al., 2014). However, the reviewed studies often ignored these relationships (e.g., a students' living situation). Feelings of isolation and not belonging are fundamentally rooted in the presence and strength of social relationships. Research has demonstrated that social self-efficacy, or the confidence to use social skills to initiate and maintain relationships, can mitigate reported severity of depression and thoughts of suicidal ideation for science, engineering, and mathematics graduate students (Bork & Mondisa, 2019). These relationships can exist in engineering graduate students' personal, professional, and academic lives, as well as any intersection of these. Supporting the growth and longevity of social supports can promote positive mental health experiences by promoting positive coping strategies and fostering a sense of belonging (Jensen & Cross, 2021).

3.4.3 More Work Is Needed to Explore the Racialized, Gendered, and Intersectional Experiences of Various Graduate Student Populations

Future work is needed to better understand the mental health experiences of international, Black, women, and Black women engineering students. Every study that focused on international graduate students discussed how the stress of being in majority English-speaking environments severely impacted their day-to-day interactions in the United States. Given the lack of non-English focused language training and limited exposure to other countries' cultures in U.S. higher education, many international students felt overwhelmed when trying to create and sustain relationships. Researchers discuss that prior to coming to study in the U.S., international students would like more information about academic cultures, established systems to assist transitions from educational settings to social settings, and additional structured opportunities to discuss research and professional development (Erichsen & Bolliger, 2011). This information could help offset feelings of isolation, which have been linked to negative outcomes, including attrition (Ali & Kohun, 2006; Laufer & Gorup, 2019).

In comparison, papers from this review demonstrate that Black graduate students are implicitly and explicitly told that they do not belong in engineering and are not expected to succeed (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). Despite these barriers, students persist, but often at the cost of their emotional and physical well-being. Some coping mechanisms may help lower psychological and behavioral stress students experience from racial microaggressions (Franklin, 2019). It is beneficial for minoritized students to have skills (e.g., coping mechanisms) to help them navigate these environments. However, this fails to recognize the systems and structures in place that enforce the hostile environments these students operate in (McCluney et al., 2021). For change to occur, accountability must fall on these systems and structures, not the minoritized students experiencing and navigating these hostile environments.

There is also an imperative need to study the intersectional mental health experiences of women and minoritized women in engineering graduate programs to identify targeted ways to support their well-being and persistence. Women were often perceived as less capable, both by themselves and others, despite performing on par with men in every study in this review (Amon, 2017; Cross, 2001; Fisher et al., 2019). Women in science and engineering often feel that they are working at an increased pace and with a higher workload than their male counterparts, and report high levels of isolation, all of which can negatively impact their commitment to their careers (Litzler et al., 2005). Black women graduate students are subject to both racial and gender stereotyping in their day-to-day interactions. Explained by the concept of intersectionality (Crenshaw, 1989), Black women engineering graduate students' experiences can be highlighted by their intersecting minoritized identities of being both Black and women. That is, they experience compounding stressors from both race- and gender-based discrimination and harassment. The limited findings from this review support the increasing calls to explore the role of intersecting identities (i.e., race and gender) have on mental health (Banks et al., 2002; Jackson, 2020).

The evidence presented in this review demonstrates that many gaps exist in engineering graduate student mental health research. These limited findings are in alignment with a report by the National Academies, which states: "[T]he research on wellbeing and mental health for graduate students remains limited in comparison to undergraduate students … effective support for graduate students would benefit from increased research and program evaluation" (NASEM, 2021, p. 83). In sum, there is much work to be done. The following sections discuss the implications of this work for engineering education and areas for future research.

3.5 Implications for Engineering Education

This work identifies three potential opportunities for the engineering education research community: (1) an opportunity to better understand graduate student mental health in engineering, (2) a need for the creation of a consistent language for discussing mental health, and (3) a need to use existing theory and frameworks when examining mental health issues. Most of the work on engineering graduate student mental health has focused on observing and broadly characterizing the state of mental health problems. First, additional work is needed to understand the current state of graduate student mental health, including how these problems form, persist, and can be prevented. The studies discussed in this work are few and largely disjointed. They spanned a variety of disciplines, including psychology, health/medicine, higher education, and engineering. There was no clear consensus for how research concerning engineering graduate students' mental health should be conducted, including what variables should be included and how those variables are defined and operationalized. To make progress in this work, researchers must help create consistency in how mental health outcomes are defined, studied, and communicated.

Second, there is a need for the creation of a consistent language for discussing mental health. A lack of shared nomenclature has contributed to the variability and inconsistency in mental health measures used and academic outcomes explored, as found in these results, and in turn, may create future disjointed work. A lack of shared terminology can make it difficult to compare findings across studies and may hinder future researchers from building on existing work (Schmidt & Hansson, 2018). Our call for co-created terminology and communication across disciplines via conscious efforts (i.e., considering research goals, researcher backgrounds, and personalities) supports existing research (Marzano et al., 2006). Moving forward, researchers need a defined set of vocabulary and guidelines for best practices when doing this work.

Finally, to help create change, researchers must be cognizant of past work. Future research must be grounded in existing theories, frameworks, and findings across different fields. Engineering education researchers have a history of drawing on the research traditions of many disciplines, including education and social science, as well as engaging in diverse research methods (Radcliffe, 2006). This review indicates future researchers should examine and use theories prevalent in other academic disciplines, such as psychology, medicine, social sciences, and public health, to both situate their work and propose new theories and frameworks to understand engineering graduate students' experiences with mental health. This will help foster new relationships and partnerships among the many different disciplines and stakeholders interested in this field of study.

3.6 Future Research and Practice

This review helps to identify several salient opportunities for future research and practice: (1) seek to standardize what is reported, (2) explore both positive and negative mental health outcomes, (3) explore population level data, (4) purposefully explore the experiences of minoritized, marginalized, and underrepresented students, (5) expand research on the student-advisor relationship, (6) explore the role of social supports outside of the advising relationship, and (7) increase research and dissemination on mental health interventions.

The first recommendation for standardization begins with providing basic summary descriptive statistics of demographics, standard mental health measures, and academic outcomes, in research conducted as detailed in Table 3-11. This work has demonstrated a need to challenge assumptions of heterogeneity in mental health experiences based on core identity groups (e.g., race, gender, nationality, etc.). Future work should include details of the intersections of variables that are known to impact one another as they relate to desired outcomes. Although Table 3-11 focuses on individualistic traits, when studying mental health, it is equally important to consider what and how current systematic structures can impact individuals' mental health (Garcia et al., 2017; Pearson et al., 2022). For example, how would an institution's size or culture impact students' comfort with reporting experiences of assault or seeking help in those situations?

The second recommendation is to include both positive and negative measures when reporting mental health outcomes. To promote positive mental health experiences, researchers must first uncover what these are and how they are experienced. For example, interviews could be conducted to ask graduate students to reflect on how they celebrate their successes. The third recommendation is that researchers must explore population-level data for engineering graduate

Table 3-11. Metrics to consider including in future studies on engineering graduate students' mental health.

Demographics	Academic discipline (and sub-discipline)
	Age
	Children/Dependent status
	Citizenship/Nationality
	Disability status
	Race/Ethnicity
	Financial support/income (past, current, & future)
	First generation status
	Gender/Sex identity
	Living situation
	Relationship status
	Socioeconomic status (past, current, & anticipated future)
	Sexual orientation
	Time in United States/length of stay
	Veteran status
	Year in program
Academic Outcomes	Academic/Degree milestones
	Attrition/Graduation rate/retention
	English language competency
	GPA (past & current)
	Post-Graduation career intentions
	Publication rate (conferences, manuscripts, author Order)
	Research environment/climate
	Resource utilization (e.g., writing centers, financial assistance, etc.)
	Time to degree completion (anticipated, actual)
	Time with advisor
Mental Health Outcomes	Coping habits
	Emotions (feelings or affective states)
	Existing mental health problem(s) (e.g., anxiety, depression, stress, etc.)
	Help-seeking and treatment utilization
	Life satisfaction
	Motivation(s) to persist
	Perceptions of environment
	Perceptions of self/self-esteem
	Relationship(s) (advisor, friends, family, peers, and/or significant other)
	Self-harm and/or suicidal ideation
	Self-image (e.g., imposter syndrome)
	Sense of belonging
	Work-life balance

students (e.g., via the Healthy Minds Network Healthy Minds Study, the American College Health Association's National College Health Assessment, etc.). This may help uncover what experiences are shared and what experiences are distinct in a setting with students from a variety of backgrounds and experiences. For example, presenting differences in reported outcomes by race, gender, ethnicity, nationality, and their potential intersections can provide both vital information for specific communities as well as highlight how the population overall is coping. Fourth, future work needs to build on and expand the mental health experiences of international, Black, women, and Black women graduate students by utilizing targeted sampling strategies to explore these populations' experiences. This should include Indigenous and Latinx graduate students, who were not the focus of any studies. In addition, no study in this review discussed the experiences of transgender or non-binary engineering graduate students or provided results outside a sex-based gender dichotomy. Students whose gender does not match gender assigned at birth or is outside of the female-male binary are four times more likely to have at least one mental health problem and over three times more likely to have seriously considered suicide in the past year (Lipson, Raifman, et al., 2019). Future work also needs to expand to include underrepresented graduate student groups (e.g., first-generation, gender-nonconforming, lower socioeconomic backgrounds, veterans, etc.).

Similarly, regardless of method choice (i.e., qualitative, quantitative, mixed methods), researchers should first consider their positionalities and biases that can impact the work as not doing so can raise serious validity concerns for the findings (Garcia et al., 2017; Hampton et al., 2021; Pearson et al., 2022; Secules et al., 2021). It is equally important to elect methods that adequately answer the research question(s) posed. For example, qualitative methods or mixed methods could be used to explore minoritized engineering graduate students' lived experiences and any culturally relevant factors that may influence these experiences. This could help ensure that the mental health experiences of minoritized populations are being holistically considered and align with the aforementioned recommendation (NASEM, 2021). Chao and Green's (2011) multiculturally sensitive mental health scale provides an acute example for how to examine experiences of racism in a mental health diagnostic instrument. Although their scale targeted African Americans, leveraging similar mixed research-methods would enable an expansion of these instruments to improve the assessment of minoritized engineering graduate students' experiences.

The fifth recommendation is to expand research on the student-advisor relationship. This relationship is central to graduate students' experiences, and a positive relationship with one's advisor can help reduce burnout and improve overall experiences (Nagy et al., 2019). Future work might explore implementation of formal training for all graduate student faculty advisors on ways to create an environment that promotes students' well-being, such as at the University of Minnesota's Chemistry department. Researchers shared how the department worked to help support students' mental health by empowering students and revising departmental policies to increase feedback from their advisor (Mousavi et al., 2018). Similarly, a recent study at 12 colleges and universities found that faculty welcomed professional development trainings about student mental health and that over half believed they should be mandatory (Boston University School of Public Health et al., 2021). NASEM recommends institutions of higher education "provide and require faculty training on how to create an inclusive and healthy learning environment" (NASEM, 2021, p. 15) . These trainings could make a difference in students' ability to seek support in serious cases of assault and discrimination, potentially improving their academic and professional careers.

The sixth recommendation is to extend research on social supports past the advising relationship. As discussed previously, experiences students have within their program, department, and institution can influence their mental health. For example, the impact of a mentoring ecosystem could be explored to understand how moving past the traditional student-advisor model can improve students' feelings of isolation, lack of support, and poor sense of belonging (Mondisa et al., 2021). Other studies could explore interventions like the Dissertation House Institute (DHI), but with different academic milestones (e.g., first semester on campus, candidacy exams; Carter-Veale et al., 2016).

This extends to the seventh recommendation, to increase the number of intervention studies. If engineering education researchers do not understand for whom, why, or how mental health problems persist in this population, it is difficult to consider what interventions should be initiated. Although current research can point to factors and variables important to engineering graduate student mental health, without intervention studies I do not know what efforts lessen or prevent mental health problems. For example, international students called for more explicit discussions on the norms and expectations of graduate school (Erichsen & Bolliger, 2011). There are the beliefs, values, and assumptions each discipline has about their practices, coined as the "hidden curriculum." Although these can be communicated in the classroom (explicitly or implicitly), taught informally, or not taught at all (Villanueva, Gelles, Stefano, et al., 2018; Villanueva, Gelles, Youmans, et al., 2018) It might be helpful for institutions to provide an introductory course for graduate students to address elements of the hidden curriculum. For example, a course might discuss professional development skills (e.g., networking, research talks, etc.), research skills (e.g., how to read scientific articles, etc.), specific retention concerns (e.g., mood disorders, funding modalities, etc.), and stigma surrounding mental health (Reavley

& Jorm, 2010; Yamaguchi et al., 2013). Engineering education researchers need to embrace and adopt best practices from other fields while actively creating a community of learning to benefit all who participate. Cumulatively, these areas of research can help uncover what factors allow negative experiences to persist and what changes need to be made to better support engineering graduate students' well-being.

3.7 Conclusions

This ScLR has demonstrated the limited range of work examining engineering graduate student mental health. Of the 19 studies included in this review, eight of them have been published between 2015-2019. This mirrors the overall rise in focus on mental health in higher education populations. However, graduate students generally and graduate students in engineering are understudied, as this review demonstrates. The studies did report diverse trends of research methodologies; however, the work is fragmented and lacks consistency. Given that half of the studies in this review did not specifically separate engineering graduate students in their results, engineering education researchers should help contribute to this literature.

Researchers can leverage existing work, ground future research in established theories and frameworks, and situate the findings in the context of the field. To be successful in studying mental health, we need to work towards developing credible interview protocols and validated, reliable survey instruments. These efforts will enable the expansion of research to encompass both understanding what is occurring in terms of graduate student mental health, why these patterns exist, and how to prevent negative outcomes. Researchers must work to establish a set of standardized vocabulary and variables. Establishing these guidelines will help foster a community of practice about engineering graduate student mental health. This will encourage dialogue between stakeholders already studying this field and encourage interdisciplinary collaborations. It is essential for stakeholders to be able to make informed and evidence-based individual, programmatic, and administrative decisions to improve the well-being of students. These results cannot be achieved without intentional efforts to foster communication across disciplines.

The increasing prevalence of mental health problems in higher education brings an awareness to understudied and at-risk populations. A lack of empirically based research limits the ability to not only understand what is going on, but also why it occurs. With the current state of research and the ever-increasing mental health crisis, it is vital to establish a research agenda that intentionally bridges the existing disjointed efforts and progresses the understanding of systemic mental health problems. Engineering education researchers can fully explore engineering graduate students' mental health, and then explain why certain patterns exist. This may lower the risk of failure for intervention and programmatic efforts addressing these needs. Robust study design and standardizing how new findings are discussed can help create more effective and inclusive engineering education programs that cultivate healthy and thriving engineering professionals.

3.8 Acknowledgements

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Chapter 4 Leveraging Photovoice to Examine Graduate Students' Mental Health Experiences within the Culture of Engineering[4]

This chapter details my photovoice study. This study was designed to examine engineering graduate students' range of mental health experiences and determine how, if at all, the culture of engineering impacted these experiences. I first begin by outlining the motivation for this study before overviewing the guiding research method (i.e., photovoice) and two theoretical frameworks (i.e., Bronfenbrenner's Ecological Systems Theory and Godfrey and Parker's Culture of Engineering Education Framework) used to conduct the study. I will then give an overview of the study design, detailing the research team, our positionalities, the study site, and how participants were recruited. Next, the methods I used to conduct the study and collect the data are detailed before I present how I analyzed the data. I then detail the results from this study, discuss the findings alongside relevant existing literature, and present limitations for this work. I end this Chapter by discussing recommendations and potential areas for future work and then summarizing the key findings from this study. This Chapter will detail how engineering graduate students' experience a range of mental health experiences (i.e., positive, negative, and mixed) that covered six themes (i.e., activities, culture, identities, mental health and emotional experiences, quarantine life, support structures). Furthermore, this Chapter will detail how the culture of engineering had a largely negative impact on engineering graduate students' mental health experiences. To support students' academic success and retention within engineering,

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Portions of the chapter are modified and adapted from [4]Bork, S. J., & Mondisa, J.-L. (2021). Using Photovoice to Examine the Mental Health Experiences of Engineering Graduate Students during COVID-19 (Work in Progress). 2021 ASEE Annual Conference & Exposition Proceedings.

work must be done to change the culture of engineering (e.g., reduce stigma around mental health and help-seeking, reform policies and practices, work towards aligning actions and behaviors with intended outcomes and goals, etc.). Future work can seek to extend these findings to other institutions as well as possible interventions to support a diverse population of engineering graduate students.

4.1 Introduction

Reported mental health problems for science and engineering graduate students are continuing to rise, with suicidal ideation doubling among college aged individuals over the past decade (Bork & Mondisa, 2022; Eisenberg et al., 2013; Lipson, Lattie, et al., 2019; Martinez & Nguyen, 2020). Recently, the Healthy Minds Network and ACHA-NCHA collected data during the COVID-19 pandemic (between March and May 2020) from 14 U.S. colleges and universities (the specific breakdown of sites and participants are detailed in (The Healthy Minds Network & American College Health Association, 2020). Findings indicated decreases in psychological wellbeing and an increased difficulty in accessing mental health care (The Healthy Minds Network & American College Health Association, 2020). Accessibility of mental health resources is a critical concern as college and university campus counseling centers are unable to keep pace with students' counseling needs and academic progress is tied to students' mental health experiences (LeViness et al., 2017). Research has detailed that students' academic success (e.g., academic performance, research productivity, intentions to persist) is connected to their mental health (Andrews & Wilding, 2004; Bork & Mondisa, 2022; Dotson et al., 2008; Eisenberg, Golberstein, et al., 2009; Laukka et al., 2018; Lipson et al., 2016; Lipson & Eisenberg, 2018; Rock et al., 2014), and that undiagnosed and untreated mental health problems can affect students' satisfaction, academic performance, research productivity, and intention to persist (Andrews & Wilding, 2004; Anttila et al., 2015; Danna & Griffin, 1999; Eisenberg, Golberstein, et al., 2009; Lipson & Eisenberg, 2018). It is important to understand not only the mental health concerns relevant to students, but also the potential protective factors that can reduce or mitigate the impact of negative mental health experiences.

A recent scoping literature review examining literature through August 2019 revealed a gap in knowledge on engineering graduate students' mental health experiences (Bork et al., 2019; Bork & Mondisa, 2022). Five databases (PubMed, PsycINFO, Scopus, CINAHL, and ERIC) were searched for any articles discussing engineering graduate students and mental health related topics (e.g., affective responses, coping strategies, etc.). Only 19 of the 4,826 unique articles fit the criteria. Comparison between these studies was limited due to a lack of shared nomenclature and as most of the papers focused on understanding the experiences of specific student groups (i.e., Black, female, Black female, and international students; Bork et al., 2019; Bork & Mondisa, 2022). However, review of these studies revealed both shared and differing experiences among these different student populations, hinting that there may be something about the norms and expectations of graduate school impacting these experiences (Bork & Mondisa, 2022). Additionally, research has demonstrated that confidence in reaching out and developing connections (i.e., social self-efficacy) is associated with significantly lower reported depression and suicidal ideation in science, engineering, and mathematics graduate students (Bork & Mondisa, 2019). However, engineering students have been found to have much lower help-seeking behaviors compared to other disciplines (e.g., humanities and arts; Lipson et al., 2016).

This study was aimed to develop a better understanding of the lived mental health experiences of engineering graduate students and how, if at all, the culture of engineering influences the mental health experiences of engineering graduate students. That is, I hoped to understand engineering graduate students' perceptions of mental health, how they view their own experiences with mental health during graduate school, and how these experiences are informed and shaped by the culture of engineering. I did this by leveraging the participatory action research method – photovoice, two theoretical frameworks, and the following two research questions:

1. *How do engineering graduate students at a large, public historically White institution describe their mental health experiences (phrased as "emotional experiences")?*
2. *How does the culture of engineering influence the mental health experiences of engineering graduate students at a historically White institution (HWI)?*

The following sections overview the participatory action research method – photovoice before defining the two guiding theoretical frameworks and outlining how they were used in this study.

4.1.1 Guiding Research Method - Photovoice

This study leveraged the established participatory action research method of photovoice, also known as photo elicitation or participatory photography, that uses photographs to empower participants to reflect on, capture, and share their lived experiences (Guajardo, 2018). There are three main goals of photovoice: (1) to allow participants to document and reflect on their community and experiences, (2) to initiate and hold conversations about issues central to participants using photographs, and (3) promote action by reaching policymakers and those who can enact change (Catalani & Minkler, 2010; C. Wang & Burris, 1997). Study participants are viewed as co-investigators of the work, working with the research team to understand important community issues by leaning on their expertise through their lived experiences (Merriam & Tisdell, 2016). The primary data source comes from the collection, sharing, and grouping of images and captions taken and/or collected from the participants in response to a prompt provided by the research team. Throughout the process participants are asked to reflect on and capture aspects of their lives.

Photovoice has been used to empower participants and promote dialogue about important community issues, lending itself to research where linguistic or communication barriers are present (Strack et al., 2004; C. Wang & Burris, 1997). As it can be difficult for individuals to discuss mental health, photovoice will provide a crutch and catalyst for interviewees when discussing this emotionally charged and difficult topic (Ha & Whittaker, 2016; Weinstein et al., 2019). Photovoice has been found to be effective in helping to answer mental health research questions. For example, Weinstein et al. used photovoice to explore the experiences of obese adults on assistance programs and their struggles with access to healthy food options (Weinstein et al., 2019). Ha & Whittaker used photovoice to understand the communication barriers and alienation experienced by children with autism spectrum disorder. In terms of higher education studies, a 2017 study used photovoice to understand the pursuit of leadership experiences by women in STEM (Amon, 2017). Although the prompt was not directly related to mental health experiences, discussions included conversations about personal and professional costs of these pursuits, the need for resiliency, and reliance on social supports (Amon, 2017). These studies illustrate the applicability of photovoice to answer descriptive research questions about mental health experiences. Bork & Mondisa provide additional details on how this study was designed and its applicability for studying engineering graduate students' mental health (see 2021).

4.1.2 Guiding Theoretical and Analytical Framework - Bronfenbrenner's Ecological System Theory

In conjunction with the photovoice research method, Bronfenbrenner's ecological system theory

(EST) was used as a guide for this study in two ways (Bronfenbrenner, 1979). First, I used EST to shape the overall design and data collection for the study by using the framework to consider *where* engineering graduate students' mental health experiences could have taken place and how these interactions may be represented differently across the different environmental levels. Second, EST was used as an analytical framework to organize the data collected and form individual participant profiles. That is, data collected from participants was organized based on the level of EST it fell into, thereby filling out and creating the participant profiles.

Bronfenbrenner's ecological system theory (EST) was introduced in 1979 to describe the ecology of human development. This theoretical framework situates individuals within the context of their local environment(s), global environment(s), and social interactions while acknowledging the influences of context, power dynamics, and the stages of development individuals experience (Reid, 2020). There are several underlying assumptions of this framework: (1) a person is ever-changing and has the ability to influence their environment, (2) just as an individual can influence their environment, the environment can influence an individual, and (3) an individual's indirect environment (i.e., a direct environment for someone they interact with) has just as much ability to influence them as does their own direct environments from connections between these settings (Nair, 2019). How much an individual can influence their environment has changed as Bronfenbrenner's model has evolved. Initially thought of as a passive role (e.g., an individual affects the environment simply by being a part of it), has evolved into a more active role, account for one's access to resources, characteristics, and desire to change their environment as factors that can facilitate and motivate these changes (Tudge et al., 2009).

To situate this model, Bronfenbrenner provided a visual representation of an individual's life as a series of embedded ecological systems (Bronfenbrenner, 1979). As detailed in Figure 4-1, these embedded systems place the individual at the core; this is because each individual has a different set of identities, past experiences, knowledge, and beliefs that influence the way they see the world and interact within it. From there, the model moves outward to the microsystem (direct environment), mesosystem (connections across microsystems), exosystem (indirect environments), macrosystem (social and cultural values), and chronosystem (changes over time), respectively. Table 4-1 also provides information going over system level definitions, scope, and examples for engineering graduate students. Generally, experiences felt more strongly and directly by individuals are near the core of the model with more distant interactions in the outer layers (Nair, 2019). This visual representation demonstrates that EST can be used as an organizational tool to help map interactions between different ecological systems. Also, this model provides a language for communicating important factors, interactions, contexts, levels, and stakeholders. Finally, following the recommendations of Tudge et al. (2009), I explicitly name how this model was applied in this study. I recognize that there has since been a revision of Bronfenbrenner's initial model, named the bioecological model. Although there is research surrounding this adaptation, in this work Bronfenbrenner's initial ecological systems model is the one used in this study.

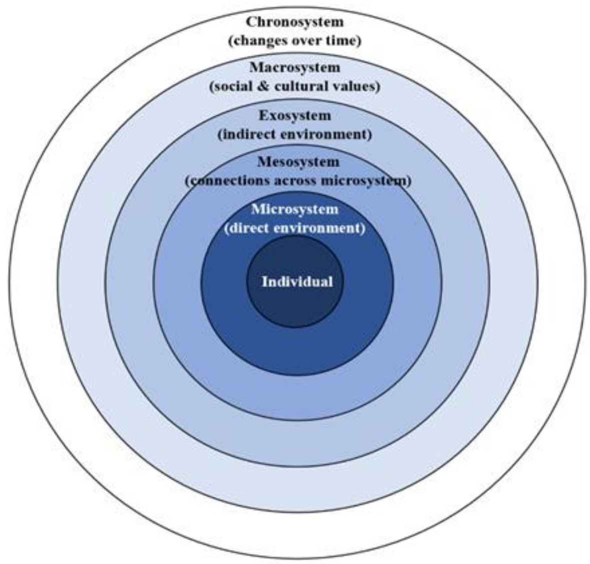

Figure 4-1. Visual representation of nested ecological system model (Bronfenbrenner, 1979).

Table 4-1. Overview of the Ecological Systems Theory (EST) System levels (Bronfenbrenner, 1979).

System Level	System Scope	Definition	Engineering Graduate Student
Individual	person of interest	demographics and identities	age, sex, race
Microsystem	direct environment	activities, roles, interpersonal relationships	courses, research lab, social settings
Mesosystem	connections across microsystems	crossover with two or more settings	shared content in research and courses
Exosystem	indirect environment	settings not actively apart of but influenced by	parents' views on your degree field; academic policies of your program
Macrosystem	social and cultural views that exist in any lower order system	belief systems, ideologies, norms, attitudes, or expectations informing and/ or influencing participation in other systems	expectation of working long hours; norms of "home" discipline; experience before joining grad school; social class
Chronosystem	individuals or surrounding environments	transition periods for both the individual and surrounding environment	Individual: life transition (e.g. marriage) Environment: COVID-19

Recent applications of EST vary. Some studies looked at specific ecological levels. Nair (2019) focused specifically on the micro- and mesosystem levels when studying meaning making in an introductory physics course. Other studies use the model in its entirety, such as a study exploring African American familial dynamics and the role of larger societal forces (McLoyd et al., 2005) or a United Kingdom study exploring how to better support higher education refugee students' psychological wellbeing (Jack et al., 2019). EST has also been used frequently in counseling psychology disciplines, including counselor training environments (Lau & Ng, 2014), studying mentoring practices of minoritized counseling/clinical psychology students (Chan et al., 2015), and development of a survey for a counseling training environment (Lau, 2012). Several dissertations related to mental health and wellbeing have also applied EST to anchor the body of work. This includes exploring minoritized graduate psychology students' experiences (Wimms, 2009); Chinese students' higher education aspirations (Q. (Joy) Zhao, 2008); the lived experiences of Australian students and different factors (personal, home, and university) that were related to their mental health (Usher, 2020), the professional development of biology graduate students (Reid, 2020); and the creation of new conceptual models (De Silva, 2018; Kahana, 2009). Finally, not all published work has used EST in isolation. For example, work has leveraged both Bronfenbrenner's ecological model and Vygotsky's sociocultural theory to explore interactions and professional development opportunities between third grade teachers and culturally, linguistically, and economically diverse students (Nason, 2012). This was done by leveraging these theories' shared emphases on the context of the situation (e.g., environment, time, surrounding life events, etc.).

For this study, EST was used to situate engineering graduate students' mental health experiences within the context of their local environment(s), global environment(s), and social interactions while acknowledging the influences of context, power dynamics, and the stages of development individuals experience (Bronfenbrenner, 1979; Reid, 2020). I used this framework to shape the overall design and data collection for the study, using the framework to consider *where* engineering graduate students' mental health experiences could have taken place and how these interactions may be represented differently across the different environmental levels.

4.1.3 Guiding Theoretical Framework - Godfrey and Parker's Culture of Engineering Education Framework

This study leverages Godfrey and Parker's Culture of Engineering Education Framework, or CEEF (Godfrey & Parker, 2010). Godfrey and Parker sought out to develop a framework to situate engineering education and to understand dimensions of the culture of engineering, including the goals of the discipline and believed pathway to achieve those goals (Godfrey & Parker, 2010). This framework was developed from an ethnographic research case study within the school of engineering at a "large, high ranking, research-led university in New Zealand", with most data collected in 1998 (Godfrey & Parker, 2010, pg. 7). Their analysis utilized an interpretivist research approach to understand what the culture of engineering education was and why it was that way. Their findings revealed six dimensions of engineering education: an engineering way of thinking, an engineering way of doing, being an engineer, acceptance of difference, relationships, and relationship to the environment. Figure 4-2 provides a visual representation of this framework, and Table 4-2 provides an overview for each of the six dimensions in the framework.

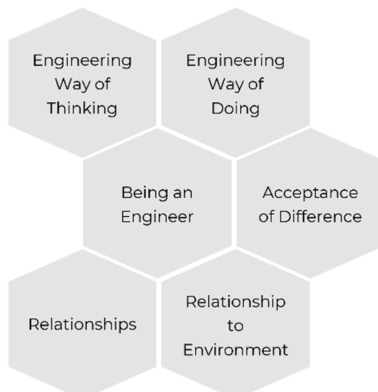

Figure 4-2. Culture of Engineering Education Framework (CEEF; Godfrey & Parker, 2010)

Table 4-2. Overviewing the six dimensions of Godfrey & Parker's Culture of Engineering Education Framework (CEEF; Godfrey & Parker, 2010)

Dimension	**Overview**
An Engineering Way of Thinking	Unique ways of knowing or conceptualizing information as an engineer
An Engineering Way of Doing	Beliefs and/or assumptions on how teaching and learning occurs within engineering education
Being an Engineer	Common attributes and/or attitudes associated with being an engineer
Acceptance of Difference	Considering the homogeneity and/or diversity of thoughts and/or values within engineering
Relationships	What relationships exist and/or the appropriate ways relationships are established and maintained within engineering
Relationship to Environment	Assumptions and beliefs held regarding engineering education's operation within several environments, including a campus environment, an institutional environment, the broader environment of higher education, engineering as a profession, and the cultural landscape of the geographic location (e.g., politics, economics, etc.)

Broadly, an engineering way of thinking encapsulates the unique ways of conceptualizing or knowing information specific to engineers, whereas an engineering way of doing refers to commonly held beliefs and/or assumptions for how teaching and learning occurs within engineering education. The dimension of being an engineer consists of common attributes and/or attitudes associated with being an engineer, rooted in the belief that there are inherent qualities attributed to engineers that fit in and succeed within engineering. Acceptance of difference is the dimension that considers the homogeneity and/or diversity of thoughts and/or values within engineering, and whether homogeneity and diversity are desired. Relationships as a dimension discusses the relationships that exist within engineering education, as well as the appropriate way these relationships are established and maintained. Finally, the dimension of relationship to the environment acknowledges that engineering education operates within several additional environments (i.e., a campus environment, an institutional environment, the broader environment of higher education, engineering as a profession, and the cultural landscape of the geographic location), and that there are assumptions and beliefs about how these environments interact with engineering education.

These six dimensions from the CEEF were used within this study to guide the analysis pertaining to the culture of engineering. That is, this framework was used to provide specific dimensions and themes that describe the culture of engineering education that I used to guide the analysis. To conduct this analysis, a codebook was generated from (Godfrey & Parker, 2010) by the first author, outlining and defining the themes that fell under each of the six dimensions. This codebook was then reviewed and finalized with the help of three other researchers. The first is a senior doctoral student who has applied this framework to mixed methods projects related to mental health for three years. The second is a doctoral student who had used this framework for over two years as a guiding framework for their dissertation work. The third individual is a research scientist who was in the process of applying this framework to other projects in a leading and supporting role for almost a year. Collectively, these individuals have expertise applying this framework qualitatively and quantitatively (e.g., developing interview protocols, developing survey items, data analysis, etc.) that was leveraged in this process. The final resulting codebook is provided in Table 4-3. As detailed, each dimension has three to seven themes identified, with a total of 28 themes across the six dimensions. These 28 themes were the concepts I focused on in our cross-case analysis (i.e., I examined participants' experiences of these themes before comparing experiences between participants). Additional details on how this framework was operationalized and used for analysis are provided in the data analysis section.

Table 4-3. Godfrey & Parkers' Culture of Engineering Education Framework Codebook (2010)

Dimension and Themes	Definition
An Engineering Way of Thinking	
Math is infallible, innocent, and/or pure	Math is reality. It can't lie or be biased. Engineers trust in math.
Strong prevalence of visual communication	Work done is usually definable and measurable. Rely on graphics, diagrams, or other visuals to transmit knowledge. Verbal communication can support it, provide order, justification, ideologies, but not primary source of knowledge.
Problem solving and design	Engineering thinking is dominated by reductionist and top-down methods (i.e., breaking down into tangible components) for problem solving. Often guided using mathematical formulae and/or estimation. Design is used to exercise and apply knowledge on engineering applications.
"Best" not "right" answers	Use of contextual factors to drive the answer. Mathematical assumptions or models help calculate and answer and define the problem space. At the same time, external demands and/or assumptions can alter the confines of the problem, and therefore drive which answer is "best."
Objectiveness in math and science	This is an assumption that the mathematical procedures, scientific processes, and the laws on which problem solutions were based were race and gender free. Therefore, when using math, it is also race and gender free, regardless of methods or user (e.g., problem solving, teaching, or assessment).
An Engineering Way of Doing	
Hardness	The difficulty and hardness of engineering and its curriculum in innate, valued, and respected. It is acknowledged that not everyone will be able to make it. Furthermore, engineers de-value work/disciplines that are easy or soft are not as valuable. This is also a gendered aspect, where hard is coded as masculine and soft is coded as feminine.
Take it	Those who wish to enter the profession need to accept the difficulty and endure it, or not you are not fit for the field. Learning is equated to suffering and hardship, and being able to endure and succeed in this environment leads to a bootcamp mentality and shared sense of pride and achievement for having made it.
Approach problem solving using a toolkit	Engineer's education is centered on gaining expert knowledge and a "tool bag" of skills that can then be applied to solve any problem.
Professional development is conditionally valued	Professional development is viewed as a nontechnical skill, separate from engineering concepts and curriculum. It is considered soft and easy, and therefore only valuable within engineering professional settings when/where the skills are useful.
Cooperation and Competition	Competition and cooperation are accepted within engineering. Students compete for grades and opportunities. At the same time, students share in their suffering, and can choose (or at times have no other option) than to work together to survive their program.
Education is used for credentials	The degree and education in engineering are valued as they provide proof of a qualification. Once obtained, this provides opportunities.
Time is a resource to be managed	Time is a resource to be managed. This is paired with a learning environment that has a heavy workload and stringent time constraints/deadlines on the workload. Therefore, despite time being often constrained and limited, individuals are expected to manage this and meet expectations set.

Being an Engineer	
“Can-do” attitude	Those who enter engineering are high achievers, above average in math and science, and proactive towards problem solving. If perceived to fit this criterion, you will be trusted by peers. This is demonstrated in the ability to divide and delegate tasks with the trust they will be completed to expected standards.
Think in bullet points	Engineers think in bullet points. They value logic, and communicate in a step-by-step, organized fashion rather than descriptive, flow sentences.
Stereotypes	Engineers typically follow a set of characteristics: numerating, practical, mentally tough, emotionally steady, conservatively mannered, pragmatic, self-depreciative, and unconcerned with appearance.
All or nothing	Engineers throw themselves into whatever activity they are doing, whether that be work or relaxation (work hard, play hard).
Being one of the “guys”	Engineering is a male-dominated field. With that comes expected behaviors (e.g., profane language, semi-sexual innuendos, sport metaphors, etc.). Women, even if respected in the discipline, are othered and viewed under a misogynistic lens.
Pride in being an engineer	Engineers believe in a meritocracy, and as part of a group that works hard, there is this shared mentality that culminates in a sense of pride and solidarity of belonging to that group. This manifests itself in language, publications, dress, how they see themselves compared to the rest of the university, and the discourse around framing the degree as “hard.”
Dimension and Themes	**Definition**
Acceptance of Difference	
Homogeneity	There is a high degree of homogeneity within the attitudes, beliefs, norms, and values engineers are expected to hold and/or conform to. There is also an assumption the engineers have similar backgrounds and experiences (e.g., education).
Conditional acceptance	Individuals are always being assessed for inclusion, and those with differences may feel it is conditional based on their ability to assimilate and/or hide/downplay what makes them different and conform to aspects under the dimension *being an engineer*.
First impressions	Within engineering, individuals initially form relationships based on what they perceive other’s abilities are within engineering and how much they expect them to succeed and/or support their own personal success. Initial relationships are based on shared interests and backgrounds as these can be leveraged as social capital and build trust, and at the same time, are usually biased by personal biases and prejudices. Minoritized individuals find that acceptance and respect for them within the discipline to be a slow, painful, and long process as their backgrounds and experiences were atypical within engineering, accentuating them as different.
Prove yourself	Individuals may change their perceptions and/or level of acceptance for "others" who persist within engineering after they have sufficiently proven their abilities, often combating unspoken prejudices and biases and/or being forced to assimilate (i.e., burden of proof on othered individual to show not what they expect them to be).
Relationships	
Collaborative	Engineering is largely collaborative and stems from a shared struggle mentality. The degree of collaboration can vary based on the situation and institution's priorities.
Mates	It behooves students to form friendships with peers in engineering (e.g., difficulty of academics, time constrained, time will spend in engineering, be seen as belonging). Not doing so can increase difficulty of major and ostracize them.
Student – faculty interactions	Students are aware of the power and generational differences that exist between them and staff/faculty. At the same time, as teaching/mentoring relationship develops, trust and rapport can build allowing for interactions to become more informal (blur differences).
Relationship to Environment	
Situated within several embedded ecosystems	An individual student's experience within engineering are shaped by (1) the academic environment of higher education at their own institution, (2) degree of oversight and/or involvement of the engineering profession, and (3) the cultural landscape of the nation (including political, economic, and social contexts).
Desire for autonomy and independence	Within an academic institution, engineering strives for autonomy, independence, and minimal oversight, and preference for resolving issues internally.
Inherent oversight	Although engineering desires to be self-sufficient with minimal oversight, it is still overseen by a university and held to governmental (local, state, national) and funding agency regulations.

4.2 Study Design

The following sections discuss how this study was designed. I first discuss the formation of the research team and their positionality before discussing the study site and participant recruitment.

4.2.1 Research Team and Positionality

The study team was located at a research-intensive, Midwestern, historically White higher education institution. The first team member experienced all of her higher educational training in this type of environment, which impacted her perspective. Her experiences matriculating from the field of electrical engineering to engineering education research include many of the experiences shared by participants in the study. She is aware that her identity as a first-generation, White cisgender woman in engineering with her own mental health journey can lead her to seek to validate her own lived experiences. The photovoice methodology provided a framework to minimize the impact of the potential conflicts of interests and validity concerns this may bring, most notably using the SHOWeD technique for the focus group interview dialogue (an acronym, represents a list of five questions facilitators can pose to help participants talk about the images, detailed later in the methodology section and Table 4-6; Wang et al., 2000). Furthermore, all data collection methods were piloted by the first author and discussed with the second author. This is especially important as the first author served as the facilitator for this study, leading the recruitment, training, collection, and discussions of the images and captions with the participants. Going through the process from a participants' point of view brought awareness to the specific experiences and emotions she might seek to validate or attune to as a facilitator, helping to find blind spots in the data collection and analysis process she could then plan for.

The second study team member is an African American cisgender woman with extensive research experience related to attrition and matriculation factors that influence students in higher education. She contributed to this work as a point of triangulation. Leveraging her research skills and knowledge, she challenged the rigor of the data analysis processes and interpretation of the findings through questions and conversations with the research team. Both authors engaged in discussions about all research aspects of the study to confirm the validity of their interpretations of the articles, the findings, and potential implications. Having both an engineering graduate student and faculty member in engineering as part of the study team gives invaluable insight into the culture of engineering students discussed and provided common ground to build rapport and trust with the participants.

4.2.2 Study Site & Participant Recruitment

The community of interest was engineering graduate students at a large public midwestern historically White institution (HWI) with an emphasis on research. Driven by qualitative research methods, the goal was not to seek generalizable results but rather asking questions and in-depth to elicit detailed responses to understand students' experiences (Merriam & Tisdell, 2016). Most photovoice studies range from 8-12 participants given the involved nature of the project and intense data collection (Guajardo, 2018; Ha & Whittaker, 2016; Shimshock, 2008; Trenton & Marsh, 2020; Weinstein et al., 2019). Thus, convenience sampling was used with a focus on mental health, and the desire to have diversity across participants' academic programs, degree types, gender, race, age, and citizenship status. After obtaining institutional review board approval (HUM#00192649), eight engineering graduate students were recruited by the main facilitator via email. She intentionally recruited participants from a variety of engineering disciplines, backgrounds, and positionalities. Participants indicated their interest in participating by completing the pre-screening survey. Participants provided their engineering disciplines using the National Science Foundation's reported categories (National Science Foundation National Center for Science and Engineering Statistics, 2013), and included seven engineering disciplines: bioengineering and biomedical; chemical; electrical, electronic, and communications; environmental health; materials science; mechanical; and other engineering. Given the potentially identifiable nature of this data, degree programs will not be linked to individual participants.

4.3 Data Collection Methods

Data collection took place over 2021-2022. There were five points of data collection, as detailed in Figure 4-3. This includes an initial pre-screening survey, participants' submitted images and captions, 60-minute individual interviews, a focus group interview, and a final exit survey. This section provides an overview of the methods for data collection (also provided in Table 4-4) to answer the research questions,

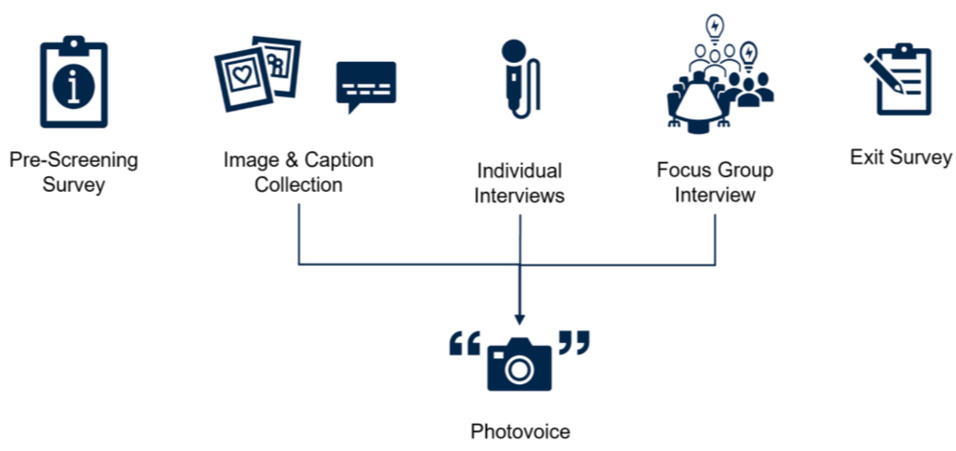

Figure 4-3. Sources of data for this photovoice study.

Table 4-4. Overview of the five sources of data collected and analysis.

Data Source	Data Collection
Pre-Screening Survey	Consent to study Information on background; demographics; engineering work culture; engineering and campus climate; academic performance; and mental health measures
Image and Caption Collection	Five images and captions on students' emotional experiences in graduate school
Individual Interviews	60-minute virtual interview, expand on images/captions and aspects of mental health
Focus Group Interview	90-minute virtual interview, using SHOWeD strategy get at groups' collective mental health experiences (Wang et al., 2000)
Exit Survey	Member checking and alignment with focus group findings

1. *How do engineering graduate students at a large, public historically White institution describe their mental health experiences (phrased as "emotional experiences")?*
2. *How does the culture of engineering influence the mental health experiences of engineering graduate students at a historically White institution (HWI)?*

The following sections will provide details on how the five sources of data were collected.

4.3.1 Pre-Screening Survey

The initial pre-screening survey was sent to potential participants via email during recruitment and created in Qualtrics. This pre-screening survey process began by reviewing the informed consent form, which included information about the study aims, compensation, timeline, and potential risks and discomforts. Participants selected whether they agreed to participate in the study based on the information provided. Those that did not agree were sent to the end of the survey, while those consenting moved on. Participants that agreed and consented to the study went on to complete the survey. The survey included questions on their background; demographics; engineering work culture; engineering and campus climate; academic

Table 4-5. Overview of the pre-screening survey sections and topics.

Survey Section	Section Item Topics
Background Information	discipline, degree program, length in program, academic milestones
Demographics	age, gender relationship status, living arrangement, race/ethnicity, international student status, children/dependents, parents/caregivers' education level
Engineering Work Culture	perceived weekly workload, workload distribution, target workload distribution, discrepancies in workload distributions, perceptions of work-life balance
Academic Performance	potential impacts, academic persistence, barriers to completion
Engineering and Campus Climate	sense of belonging, department/program belonging, community (having, assessing, describing), experienced behaviors (school and department/program), College of Engineering Climate
Mental Health Measures	depression (PHQ-9); anxiety (Beck Anxiety Inventory); flourishing (Psychological well-being; positive mental health); academic challenges, work-life balance

performance; and mental health measures, as detailed in Table 4-5. Table B-1, Table B-2, and Table B-3 in Appendix B provides details on the questions asked with regards to background/demographics, academic performance, and mental health measures, respectively. Appendix A provides additional information on the mental health survey questions asked (also found in Bork & Mondisa, 2021).

4.3.2 Image and Caption Collection

I provided information to the participants detailing the research methods, the goals of photovoice, and the safety and ethical considerations of photovoice (i.e., not intruding in someone's personal or private space, getting consent of anyone included in a photograph, etc.) before collecting images and captions from participants; this is typical for this study design (Shimshock, 2008). Images and captions were collected via a UM Qualtrics survey. The survey first asked respondents to sign-off again following all ethical considerations and provide any consent forms as needed. Then participants were asked to provide images and captions in response to the data collection prompt, as follows:

Reflect on five impactful emotional experiences of any type that you have had as an engineering graduate student here at [BLINDED]. Please try to capture the range of emotional experiences you've had. With these in mind, please select an image to represent each of those experiences. These images can be ones you have taken, ones you take or create specifically for this project, or find online. Please submit each image with a 3-5 sentence caption explaining why the image was included, and if necessary, the URL from where you found the image.

As detailed, participants were asked to provide five images and captions that captured the range of emotional experiences they have had as a graduate student. The phrasing "emotional experiences" was selected after piloting various phrasings in the study design. That is, given how stigmatized and emotionally charged mental health can be, using a prompt to indirectly ask about these experiences helped circumvent this. This also was in alignment with how mental health was defined for this study (i.e., anything relating to an individual's affective or mental state). In addition, participants had the option of using any form of visuals for their submissions, including images they had created, photos they may have captured, or even images found online (provided they included where that image came from; i.e., website address). The captions were asked to be three to five sentences in length and used to provide an overview for the image submitted and why it was included. Participants were also able to submit additional information in an open response question with regards to the image and caption submission, and that data was included. As five images and captions were collected from each participant, a total of 40 images and captions were collected across the eight participants.

After submitting their five images and captions in the online survey, participants had the option of filling in the question: *Was there another emotional experience you wanted to share,* *but couldn't find an image to do so? If so, please describe it below.* This was to provide space for participants to reflect on and share experiences that may have been difficult to capture.

Finally, many of the images provided by participants were from online sources. Given the varying levels of copyright concerns and the desire to be consistent in reporting of the data, any image found online was replaced with images either generated by the member of the research team or from an open source material online (e.g., Stable Diffusion Online, 2023). The citations for the original submitted images are included for reference when the findings are presented.

4.3.3 Individual Interviews

Eight separate 60-minute interviews were conducted, one for each participant. A semi-structured interview protocol was developed and piloted by the research team prior to use with participants. Part of this process included review and feedback of the protocol by two experts: a campus mental health professional who has expertise in graduate student mental health and a qualitative researcher with expertise exploring engineers' cultural beliefs. There were five sections of the protocol: asking background and warm-up questions, probing on participants' submitted images and captions, asking questions on mental health and engineering culture, and a cool down. Table B-4 in Appendix B details the questions asked in the interview protocol. The interviews were conducted after collecting participants' respective images and captions using the online audio and video software Zoom where they were recorded and later transcribed. In addition to probing further on the images and captions provided, interview questions inquired about participants' backgrounds, their perceptions of the culture of engineering, and their perceptions of mental health in engineering.

4.3.4 Focus Group Interview

One, 90-minute focus group interview was conducted after completing each of the eight individual virtual interviews and the initial image data analysis. Six of the eight participants participated in the focus group interview due to scheduling conflicts. Although not present, the images and captions shared by the two other participants were shared in the focus group interview, and if another participant asked about them, the respective caption was read to the group. Finally, before the focus group interview, the eight individual level image and caption codebooks created to prepare for the individual interviews were used to generate a focus group level codebook. That is, all the participants' codebooks were combined, with codes being consolidated and adjusted until saturation was met. This focus group level codebook was referenced by the facilitator prior to and during the focus group to facilitate the discussion.

The goal of this focus group was to bring together participants to discuss the images they had submitted to find commonalities, themes, or concepts shared across images and individual experiences. The specific task of the focus group was to come to a collective agreement on five to ten images that best represented participants shared emotional experiences as engineering graduate students at the same institution. This was done in two ways. Prior to the focus group, the eight separate image and caption codebooks generated for the interviews were revisited. Specifically, these codebooks were merged into one codebook in preparation for the focus group discussion. Second, in the focus group the SHOWeD strategy was used to guide the discussion (Gant et al., 2009; Trenton & Marsh, 2020; C. C. Wang et al., 2000). SHOWeD, an acronym, represents a list of five questions facilitators can pose to help participants talk about the images they include: "What do you *s*ee here? What is really *h*appening here? How does this relate to *o*ur lives? *W*hy does this problem, concern, or strength exist? What can we *d*o about it?" (detailed in

Table 4-6; C. C. Wang et al., 2000, p. 84). These questions were used by the first author to guide the focus group dialogue. This helped to guide the discussion on each participants' images as well as help direct the conversation to sort through the images to pull out the images that were representative of the group's shared mental health experiences.

Table 4-6. SHOWeD technique for photovoice group discussion (C. C. Wang et al., 2000)

Letter	Respective Question
S	What do you See here?
H	What is really Happening here?
O	How does this relate to Our lives?
We	Why does this condition Exist?
D	What can we Do about it?

4.3.5 Exit Survey

After the completion of the process, an exit survey was administered to all eight participants to serve as a member-checking process. When this survey was sent, participants were asked to read through the de-identified transcripts for their respective interview and focus group interview (if applicable) as well as their images and captions. They were given the opportunity to provide comments or suggestions to changes in the data for any reason (e.g., incorrect transcription, not appropriately de-identified, desire to redact information) prior to data analysis. This ensured participant consent on the data that would be shared and used in analysis, an important aspect given the topics being discussed. At the beginning of the exit survey, participants were required to verify that they had reviewed their transcripts and that they were to their satisfaction.

This exit survey also served as a member-checking measure on the themes that emerged in the focus group. This was done by asking participants to rank the final themes/experiences from the focus group interview, and indicate which, if any, were not applicable to them (detailed in Appendix B, Table B-5). This was important as not all participants attended the focus group.

For the two that did not attend, this served to verify what they agreed with in terms of the themes that emerged. For the six participants that attended, there may still have been differences in levels of agreement for the themes discussed, and this gave the chance to share that.

4.4 Data Analysis

This section provides an overview of how data was analyzed in this study. Some data analysis took place before all data was collected, with the major portions of data analyses taking place after all the data was collected. The first section will detail the analysis that took place during data collection, with the following two sections detailing how data was analyzed to answer the first and second research questions, respectively.

4.4.1 Data Analyzed During Data Collection

Although most data analysis was done after data was collected, some data analysis took place during data collection. Prior to each individual interview, participants' images and captions were analyzed as they were central to the interview. Analysis began with the images, looking at both the visual aspects of the image (e.g., color, brightness, etc.) and the subject matter (e.g., activity taking place, interactions, setting, etc.). One image was analyzed, and saturation of themes were met before adding in an additional image. When saturation from all five images was complete, the captions were added in. Again, this was one at a time until saturation was reached. Once all images and captions were analyzed, the participant level codebook was generated. Consolidation and revision of themes occurred until there were roughly ten codes in each codebook. These individual codebooks were referenced by the facilitator prior to and during the interview to facilitate the discussion (not shared with the participants). Outside of this, data analysis took place after all data was collected.

4.4.2 Data Analysis for the First Research Question (Describing Mental Health Experiences)

Best practices in qualitative research were used to answer the first research question, *how do engineering graduate students at a large, public historically White institution describe their mental health experiences (phrased as "emotional experiences")?* Qualitative data was primarily used, with quantitative data being used for triangulation of the qualitative findings (Borrego et al., 2009). Data integration occurred after separate analysis, resulting in a meta-inference (i.e., analyzed qualitative and quantitative data separately before building on results in a meta-inference; Creamer, 2018).

Specifically, data analysis began by reviewing data collected during the pre-screening survey. The information provided there was used to provide richness of the data used in triangulation of findings. I then reviewed the exit survey. This allowed me to check the agreement of themes and any concerns that may have resulted. The codebook generated prior to the focus group (i.e., consolidated version) was used to analyze the groupings of images and captions from the focus group interview. That is, I followed an inductive, guided coding format, analyzing one grouping at a time until completed. Once this was complete, I assessed this final image codebook for consolidation or clarification on themes and categories. I did not remove any codes, but clarified and refined codes to ensure they were unique. Once the images and captions were analyzed, analysis moved to the interview transcripts. I began with the focus group transcript. The transcript was first read in its entirety without taking notes or coding to gain familiarity with the dialogue. The transcript was then read line by line and analyzed using an inductive, semi-guided, open coding format guided by thematic analysis (Boyatzis, 1998; Glaser & Strauss, 1967b; Strauss & Corbin, 1998). That is, codes from the final image/caption codebook were used as a starting point, but in a nonrestrictive manner, such that some codes may not be used, and others added in as needed. Once completed, the resulting codebook was revised for consolidation and clarification on the themes and categories that emerged (e.g., codes merged, parsed out, consolidated, removed, etc.).

This focus group interview codebook was then used to analyze each of the individual interview transcripts. The goal for the interview data was to use it to expand on themes and information shared in the focus group. As with the focus group transcript, each individual interview transcript was first read in its entirety to provide familiarity with what was discussed before being coded. Unlike before, the coding was now restricted to the codebook that resulted from analyzing the focus group interview transcript to ensure that the analysis was centered on the group's collective experiences. Sub-categories of codes were allowed to be created in this process, but no new themes were added. Again, once complete, the resulting codebook was revised for consolidation and clarification on the themes and categories that emerged.

4.4.3 Data Analysis for the Second Research Question (Role of the Culture of Engineering)

To answer the second research question, *how does the culture of engineering influence the mental health experiences of engineering graduate students at a historically White institution (HWI),* three sources of data (pre-screening survey, captions, and individual interview transcripts) were integrated for convergent mixed methods design (Creamer, 2018), specifically to perform a cross-case comparative analysis (Merriam & Tisdell, 2016). That is, integration of both qualitative data (i.e., pre-screening survey data, captions, interview transcripts) and quantitative data (i.e., pre-screening survey data) occurred by merging the quantitative and qualitative information together to generate individual participant profiles (Fetters et al., 2013). These sources of data (i.e., pre-screening survey, captions, and individual interview transcripts) were analyzed both before and after integration, allowing for both a meta-analysis and meta-inference from the cross-case comparison analysis (Creamer, 2018).

A cross-case comparison technique was selected as it could attune to the nuanced ways the culture of engineering affected these students. That is, using this method conjunction with a guiding theoretical framework specific to the culture of engineering education enabled me to attune to specific dimensions of engineering culture, and therefore focus the analysis on the relationship between the culture of engineering and engineering graduate students' mental health experiences. This methodological approach allowed me to answer how the culture of engineering influences engineering graduate students' mental health experiences. For example, consistencies in shared experiences could suggest ways the culture of engineering may impact all graduate students whereas experiences that were inconsistent or unique to a subset of student(s) could suggest ways the culture of engineering impacts students differently. Figure 4-4 provides a visual overview for how this was done. The following sections will first detail how I generated the participant profiles for data analysis before describing how I conducted the two stages of analysis that make up the cross-case comparison technique (i.e., the within-case and between-case analyses; Merriam & Tisdell, 2016).

4.4.3.1 *Constructing Participant Profiles*

Participant profiles were created using data collected by participants via a pre-screening survey, individual interview, and submitted images and captions. To organize this data, Bronfenbrenner's ecological system theory (EST) was used. As discussed, EST was developed to situate an individual within their local environment(s), global environment(s), and social interactions while acknowledging the importance of context, power dynamics, and an

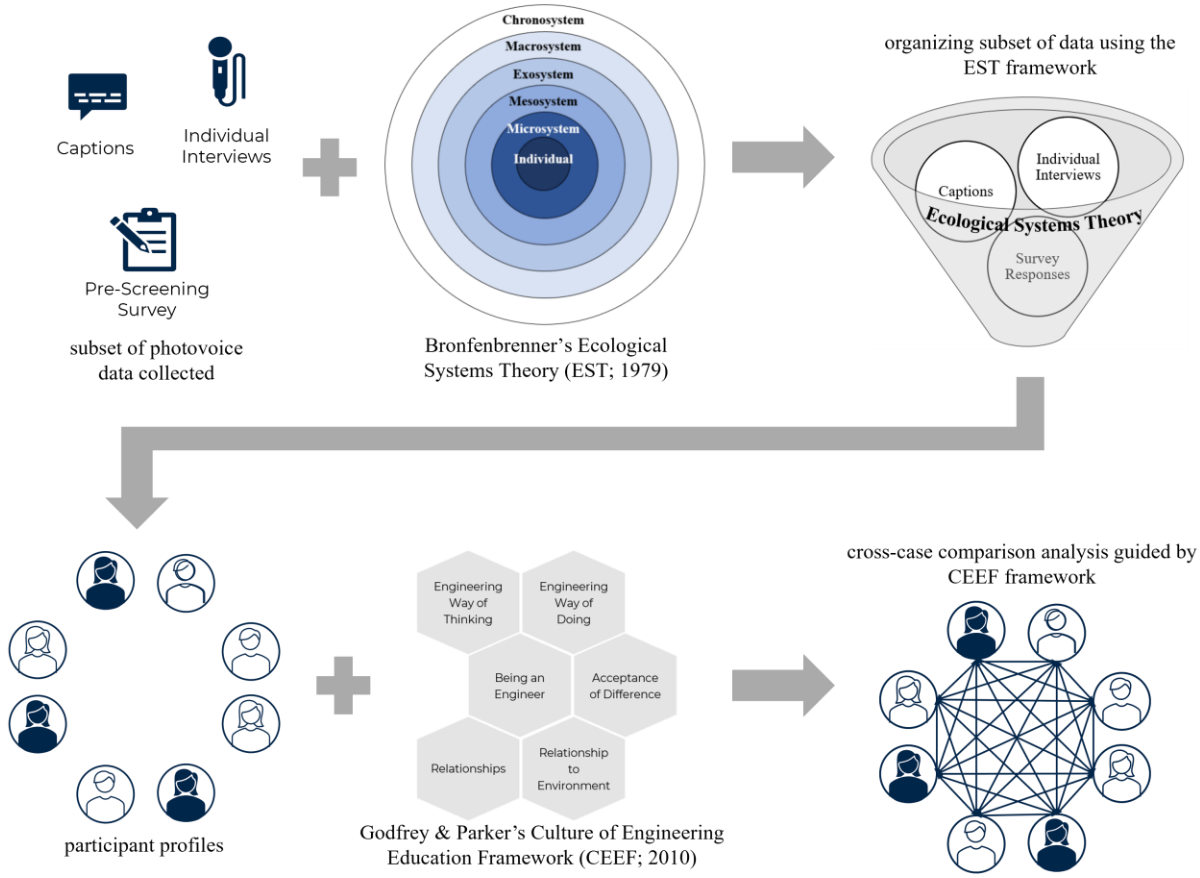

Figure 4-4. Visual representation detailing how our analytic framework (EST) was leveraged to organize data and generate participant profiles. These profiles were then analyzed in a cross-case comparison analysis by leveraging a second theoretical framework (CEEF).

individual's stages of development (Bronfenbrenner, 1979; Reid, 2020). This framework helped organize the data collected from participants as it defines an individual's life to be a series of embedded ecological systems where the individual is at the center of this system before moving outward to the five additional systems - microsystem (direct environment), mesosystem (connections across microsystems), exosystem (indirect environments), macrosystem (social and cultural values), and chronosystem (changes over time) (Bronfenbrenner, 1979). For data analysis, I leveraged EST as an analytical framework to organize the data based on the system levels of EST, thereby filling out and creating the participant profiles. As discussed previously, Figure 4-1 provided a visual representation of this model, demonstrating how EST can be used as an organizational tool. Table 4-7 details each of the layers of this model, including the system level scope and definition, as well as examples of data collected from participants that would be included in each of the system levels (Bronfenbrenner, 1979). The completed profiles were then used for the cross-case comparison analysis. The following two sections will outline the two stages of this analysis (i.e., the within-case and between-case analyses).

Table 4-7. Overview of the Ecological Systems Theory (EST) system levels (Bronfenbrenner, 1979) and examples of data

System Level	System Scope	Definition	Examples for Engineering Graduate Students
Individual	person of interest	demographics and identities	age, gender, race/ethnicity, citizenship, confidence to complete degree, satisfaction with academic experience, perceived barriers to complete degree, mental health measures (depression, anxiety, flourishing)
Microsystem	direct environment	activities, roles, interpersonal relationships	activities: milestones, workload, courses, research lab roles & interpersonal: researcher, instructor, student, caregiver, sense of belonging, advising relationship, non-advisor faculty relationship(s), community(ies), hobbies, student organizations
Mesosystem	connections across microsystems	crossover with two or more settings	shared content in research and courses; students share class experiences; students in the same courses and student organizations, interaction between academic and non-academic work, exclusionary experiences
Exosystem	indirect environment	settings not actively apart of but influenced by	partner/roommate also in graduate program; member of social support network's view of or experiences in graduate school
Macrosystem	social and cultural views that exist in any lower order system	belief systems, ideologies, norms, attitudes, or expectations informing or influencing participation in other systems	expectations for graduate school, motivations for selecting institution, perceptions of the culture of engineering and/or mental health within engineering
Chronosystem	individuals or surrounding environments	transition periods for both the individual and surrounding environment	individual: transitioning into adulthood and/or grad school, relationships, developing into an independent researcher, milestones environment: coronavirus pandemic

4.4.3.2 Within-Case Analysis

The within-case analysis began with the completed participant profiles, including data collected from survey responses, image captions, and interview transcripts. This analysis was conducted sequentially on an individual participant level as the goal was to understand each participants' individual experiences. Specifically, after reviewing one participant's profile to gain familiarity with the data, that profile was examined to determine if data corresponding to each dimension from CEEF and their respective themes were present. Themes could be discussed in many ways throughout the data; therefore, each unique way a theme was discussed was recorded, and dubbed a sub-theme. In addition to generating a high-level description of the sub-theme, data was collected on how this sub-theme related to a participant's mental health (i.e., participant's own direct labeling of the experience and/or interpretation of the affective experience, driven by their data provided, as positive, negative, neutral, or a combination of the three), where this sub-theme was discussed (i.e., caption, survey response, or interview transcript data), and the system from the EST framework that this data belonged to.

Analysis repeated until all six dimensions of CEEF were analyzed. As many of the themes and dimensions were related, this process was non-restrictive. That is, revisions to the analysis were allowed, including adding or removing data from previously analyzed dimensions. Once all dimensions were examined, a final review took place to determine if any changes or consolidations could occur within the findings. Once this was completed, the within-case analysis for that participant was considered done; however, iterations and changes to reported findings were allowed as more participants' data was analyzed so long as changes were made uniformly across participant data. This entire process (from reviewing the participant profile to examining each dimension to conducting a final review) was repeated until all eight within-case analyses were completed.

4.4.3.3 Between-Case Analysis

A between-case analysis followed the within-case analysis to complete the second stage of the cross-case analysis. The objective for this analysis was to compare participants' experiences and determine if there were any shared or differing experiences with regards to the CEEF dimensions and themes. The between-case analysis focused on one theme of the CEEF at a time. Before examining a theme, the different sub-themes across the eight participants for that theme were consolidated. That is, sub-themes across participants that contained similar content and experiences were grouped together. At the same time, although content may have been similar, each participant's mental health experience with this sub-theme may have differed. Therefore, each participant's mental health experience with this sub-theme was recorded at a high level (i.e., positive, negative, or neutral). If two or more of these categories were applicable, the response was categorized as mixed. Any participant that did not discuss or have data on a specific sub-theme was recorded as not applicable.

This aggregation of data for all six dimensions with their respective themes (and sub-themes) then enabled cross-case comparisons. To aid in this analysis, I generated heat maps for the data to provide a visualization of these experiences. Heat maps are visual tools used to represent values of data as colors. For example, Table 4-8 details the colors that would be associated with differing levels of mental health experiences, ranging from positive to negative.

Table 4-8. Key for creating the color codes for the heat maps.

Categories	Value Assigned	Color Code
positive experience(s)	1	blue
positive & neutral experiences	0.5	teal
mixed experiences (positive & negative *or* positive, negative & neutral)	0	yellow
negative & neutral experiences	-0.5	orange
negative experience(s)	-1	red
neutral experience(s)	0	grey

As alluded to by Table 4-8, participant's mental health responses were categorized (i.e., positive, negative, neutral, or mixed) and then assigned numerical values. These values were used to generate gradient heat maps. I generated heat maps for each dimensions' theme/sub-themes as well as an aggregate heat map at the higher level with all six dimensions/themes. This was done by averaging the numerical values assigned for each experience within a theme (i.e., averaging the sub-themes). As a result, most pure neutral experiences were averaged to be non-neutral (all but five). Table 4-8 details the color key for these heat maps and includes the possible mixed combinations of experiences and their respective colors: blue represents positive experience(s), teal represents mixed positive and neutral experiences; yellow represents mixed experiences that net neutral (i.e., positive and negative, or positive, negative, and neutral experiences); orange represents mixed negative and neutral experiences; red represents negative experience(s); and grey represents neutral experience(s). Numerically, mixed, and neutral experiences were assigned the same value. However, as these have different meanings, they were given different color codes.

Finally, to help determine the most salient data to discuss, I sorted the participant data based on "richness." Here, richness was determined by calculating the number of unique themes within a dimension of the culture framework (CEEF) that source of data was located in. There were 347 unique sources of data used in the analysis, as detailed in Table 4-9. Table 4-9 also details the number of unique sources of data by dimension as well as the potential source for "rich" data, or unique data that is represented in at least two themes of a dimension in the analysis. It is important to add that although there were 347 unique sources of data, data sources were not restricted to one dimension/theme. For example, there may have been a quote that could fit within three of the themes across two dimensions of CEEF. This quote would be coded for all

Table 4-9. Detailing the unique sources of data used in analysis by CEEF dimension.

CEEF Dimension	Unique Sources of Data	Unique Data in 2(+) Themes	Unique Data in 3(+) Themes	Unique Data in 4(+) Themes
An Engineering Way of Thinking	104	19	6	-
An Engineering Way of Doing	210	110	37	11
Being an Engineer	178	59	18	2
Acceptance of Difference	254	123	23	7
Relationships	140	32	1	-
Relationship to Environment	175	45	6	-

three themes. Then, within the results and discussion section of this study, the data presented was selected based on quotes that most saliently represented the theme(s) being discussed. I then end this section by discussing the limitations of this work.

4.5 Results and Discussion

In this section, I first detail findings from the pre-screening survey, the final codebook, and the exit survey. I then discuss findings to answer the two research questions of this study. That is, I first answer how engineering graduate students described their mental health experiences. After this, I present highlights on the participant profiles generated to answer the second research question before discussing the role of the culture of engineering in engineering graduate students' mental health experiences.

4.5.1 Pre-Screening Survey

This section presents the demographic and background information from the pre-screening survey. Information presented here is also available from a previous work in progress publication (Bork & Mondisa, 2021). As detailed in Table 4-10, participants included one master's student and seven joint master's and doctoral students. Four of the participants identified as White/Non-Hispanic with two participants identifying as Black/African American, one participant

Table 4-10. Participant background and demographic information from pre-screening survey (recreated from tables in (Bork & Mondisa, 2021).

Student	Degree Program	Race / Ethnicity	Gender	Age	Parents' Education	Depression	Anxiety	Flourishing
Adrian	MS/PhD	Hispanic or Latino; White / Non-Hispanic	Non-Binary	25-44	MS & HS	Minimal Depression	Low Anxiety	44/56*
Aiden	MS/PhD	White / Non-Hispanic	Male	18-24	MS & PhD	Minimal Depression	Low Anxiety	54/56
Alex	MS/PhD	White / Non-Hispanic	Female	18-24	BS & BS	Mild Depression	Low Anxiety	50/56
Diana	MS/PhD	Black / African American	Female	25-44	PhD & PhD	Mild Depression	Low Anxiety	38/56
Erik	MS/PhD	White / Non-Hispanic	Male	25-44	MS & MS	Minimal Depression	Low Anxiety	56/56
Naomi	MS/PhD	Black / African American	Female	25-44	PhD & PhD	Mild Depression	Low Anxiety	31/56
Nitya	MS	Asian or Asian American	Female	25-44	MS & BS	Moderate Depression	Moderate Anxiety	49/56
Zoey	MS/PhD	White / Non-Hispanic	Female	25-44	MS & BS	Moderate Depression	Low Anxiety	37/56

Notes: HS = high school, BS = bachelor's degree, MS = master's degree, PhD = doctoral degree; *omitted an item on this scale

identifying as Asian or Asian American, and one participant identifying as both Hispanic or Latino and White/Non-Hispanic. One participant identified as non-binary, two participants identified as male, and five participants identified as female. Using the United States census categories for age, two of the participants fell into the 18-24 category with six participants in the 25-44 category (United States Census Bureau, 2021). Only one of the participants identified as an international student. All but one student had at least one parent/caregiver with a graduate degree. Overall, only one parent/caregiver has a high school degree, four parents/caregivers have a bachelor's degree, six parents/caregivers have a master's degree, and five parents/caregivers have a doctoral degree (disciplines unknown). When considering participants' self-reported responses to the mental health measures (detailed in Appendix B), the Patient Health Questionnaire (PHQ-9) indicated three participants scores aligning with the category of minimal depression, three participants with scores aligning with the category of mild depression, and two participants with scores aligning with the category of moderate depression. As for the Beck

Anxiety Inventory (BAI), one participant had scores aligning with the category of moderate anxiety with the other seven participants having scores aligning with the category of with low anxiety. In terms of Flourishing (positive wellbeing, measure of positive mental health with higher being more positive), responses ranged from a score of 31/56 to a score of 56/56, with an average score of 44.9. Finally, with respect to perceived academic persistence barriers, mental or emotional health problems was selected by 5 participants, (62.5%), the lack of motivation or desire [to complete their degree] was selected by 4 participants (50%), and COVID-19 related delays or changes to degree was selected by 3 participants, with Erik being the only participant to not select any perceived barrier.

4.5.2 Final Codebook Themes

The final codebook contained six thematic groupings: activities, culture, identities, quarantine life, support structures, and mental health and emotional experiences. Table 4-11 details each theme, their working definition, and their respective sub-themes. Included under the sub-themes are the eight groupings generated from participants via the focus group interview. That is, during the focus group interview, participants reduced 40 separate images to 17 images across eight groupings (i.e., external supports, individual, isolated and singled out, milestones, new experiences, otherness and Whiteness, overwhelmed and unsure, and quarantine life). All themes but culture include at least one of the groupings from the focus group interview.

4.5.3 Exit Survey

The exit survey was used for member checking the findings from the focus group. Participants overall felt their experiences were represented and that the focus group interview touched on the range of meaningful emotional experiences as an engineering graduate student. At the same time,

Table 4-11. Final Codebook.

Theme	Working Definition	Sub-Themes
Activities	Something done by a person or group	milestones, academic milestones, *new experiences, research, school activities
Culture	Normative behaviors, interactions, expectations, and dynamics that exist for a specific social group	culture, expectations & norms, work life balance, tradeoff
Identities	Sets of traits, characteristics, and/or demographics used to describe an individual and/or group of individuals	*individual, *otherness & Whiteness, minoritized, international
Mental Health and Emotional Experiences	Anything related to an individual's affective state and/or impacting their emotional or mental state	emotions, coping strategies, confidence/self-worth, fun, help seeking, *isolated & singled out, motivation, negative experience, *overwhelmed & unsure, positive experience, mixed positive and negative experience, self-doubt / criticism
Quarantine Life	Aspects of living and adapting to life during the coronavirus pandemic (Covid-19)	*quarantine life
Support Structures	Relating to an individuals' network of individuals they can turn to in a time of need	support structures, *external supports, advisor, peers

*Note: The * is used to indicate codes that are aligned with the groupings discussed in the focus group.

4 of the 6 focus group interview participants indicated that there were impactful emotional experiences they were not comfortable sharing. Diana shared, *"I did not dive deep into some of the sensitive information that I was experiencing because I did not want to draw attention to myself, or feel different from the others."* Naomi shared, *"I did touch on race a little, but perhaps did not emphasize enough to do justice to what a significant role it plays in my graduate experience. I also did not touch on sexuality at all because my heavily conservative upbringing has made it difficult for me to talk candidly about the subject."* Finally, Aiden shared, *"I recognized some of the voices on the focus group call."*

When it came to ranking the impact of their emotional experiences, all but one of the experiences were perceived by at least one participant to be very salient/impactful (outside of milestones, ranked as salient/impactful). On average, ***overwhelmed and unsure*** and ***external***

supports ranked the highest (average salient/impactful or higher). When asked to rank the experiences relative to one another, on average, ***overwhelmed and unsure*** and ***external supports ranked*** the highest (averaging a rank of 3rd most impactful experience of the 8). In addition, participants could add other experiences that they felt were relevant throughout the survey. Alex was the only participant to add one, and shared, *"recently being diagnosed with ADHD and realizing I'm not neurotypical after all"* as an impactful experience.

4.5.4 Engineering Graduate Students Experience a Range of Mental Health Experiences

This section presents themes that emerged from analyzing the photovoice data to answer the first research question, how do engineering graduate students describe their mental health experiences. These findings focused on the final themes from the focus group interview and are presented in a discussion format, organized by the thematic group the sub-themes fell under (as detailed in Table 4-11), with relevant literature citations included to help ground and situate the findings. When selecting quotes, I began with the focus group transcript and chose quotes that were representative of each sub-theme. After reviewing this, I pulled quotes from individual interview transcripts to both balance the voices of participants in the findings presented and provide additional context and richness.

4.5.4.1 Identities

The identities theme was defined as sets of traits, characteristics, and/or demographics used to describe an individual and/or group of individuals. This theme encompasses two of the image groupings, ***individual*** and ***otherness and Whiteness***, with respective images in Figure 4-5 and Figure 4-6, respectively.

The setting is a paint and pour event, in which the participant and others participating were instructed to paint a self-portrait and then overlay this image with words they would use to describe themselves. In the foreground is this self-portrait depicted to be in Naomi's likeness with a cool colored background. On top of this painted in a non-vibrant, warm color are the words: CHOSEN, HAPPY, SMART, ENERGETIC, DRIVEN, LOVED, POWERFUL. In the background of the self-portrait the scene are tables lined covers and art supplies (e.g., paint pallets, the backing of other canvases, brushes, and water cups) as well as another participant.

Figure 4-5. Images from the theme "Individual". Note image on the left was converted to descriptive text given identifiable nature.

The ***individual*** sub-theme was created by participants to capture the human aspect of their experience. Figure 4-5 details the images selected by participants for this grouping as they invoked a positive sense of self. To expand on this, in their individual interview, Diana discussed how they worked over an academic seasonal break to develop a better understanding of their research. Reflecting on that experience, Diana shared:

> [Working on understanding my research and solving the problem] was one of the first times I actually felt like, okay, I am capable of figuring things out, or I can troubleshoot things. And since we weren't meeting with my advisor, I just had that time to work and process things at my own pace. And I think it was very empowering for me. And I guess it was important to me, meaningful, because it's like I spent so much time thinking no, maybe I can't figure these things out. Or you know what I mean? But now I don't know. It was just very impactful for me as a student.

As a doctoral graduate student, Diana is working to develop themselves as an independent thinker. By spending time outside of the normal working environment, Diana was able to give themselves the time and pacing needed to answer a problem in their work. This in turn was empowering, providing a sense of self-worth. This is supported by literature that has demonstrated engineering graduate students can base their self-worth on academic competence, especially for international students (Bork & Mondisa, 2022; Hyun et al., 2007; Li & Stodolska, 2006; Rice et al., 2012).

This is not the only way participants feel a sense of self-worth, though. As Zoey discussed in the focus group interview:

> I can claim the wedding photo and one of the cats … for me it's realizing that my life is not just grad school. I have a family and I have other things that also contribute to my self-worth outside of just work … [I have] those other aspects of my life.

Here, Zoey shares the sentiment that being a graduate student is not the only aspect of her life, and more importantly, these external aspects of being a cat parent and a spouse provide them a sense of self-worth that contributes to their sense of self. Alex expanded on this thought, discussing how as graduate students they still have many things that come together to make their lives whole:

> I guess having those things that also bring you joy during grad school in order to balance it out and make you realize what I think was maybe brought up earlier, I think by Zoey, about we are not just a cog in the machine of grad school, even though sometimes it feels like that. We're whole people that have multiple experiences and multiple passions and multiple things that make our lives whole.

Alex builds on Zoey's remark to reflect that even though in this setting as graduate students it can feel like you are just a small part of a larger context, but that this is not true for them. Graduate students are people as well, each with their own backgrounds, experiences, and traits that makes them who they are.

Naomi built on this further by sharing their experience at a social event where participants painted self-portraits for how they viewed themselves. This event happened after Naomi was struggling in their current program and on the verge of leaving graduate school altogether after completing their master's degree requirements:

> This [painting] event happened, and I was feeling really, really bad about myself and all that and just feeling exactly like a failure. … [the prompt was] this self-portrait thing and then you would paint over these words, like how you describe yourself, and I remember when we got to the words section of this, I was like, 'I don't know what to write here. Nothing feels good here.' And then, so this is another testament, I guess, to my support network. I had my friend saying, 'Yeah, let's pick out some words.' And they had me start saying words, I was like, 'Okay, maybe, I don't, chosen, happy. I don't know.' And my friend was like 'No, no absolutely this is right,' and kind of encouraged me to write down those words that first came to mind, even the ones that I felt like I don't think I can write smart and all that. Ones that I definitely did not end of writing, but I'm now thinking, 'Oh, I probably should've,' was I was going to write PhD, because at the time it didn't seem like I was ever going to be able to get back into a PhD program.

This event was important to Naomi. During one of the low moments during their graduate studies, when Naomi themselves were unsure if they would continue to pursue a doctoral degree, Naomi's friend showed up and broke through the internal dialogue of self-doubt and criticism. Their friend empowered Naomi to see themselves as they were, as something much more than their perceived failures. A recent publication detailed how critical events during an engineering graduate student's career (i.e., turning point event, occurring over a fixed time with a strong affective response from the person recalling the event) can have a large impact on their intentions to persist within their degree program (Zerbe et al., 2022). Critical events are often a result of several stressors that culminate in this larger event, and more importantly, are viewed as critical events after some time has passed and the individual is reflecting on their experiences (Zerbe et al., 2022). I argue that Naomi's experiences during this paint and pour served as their critical event, the tipping point, that without, may have resulted in Naomi not pursuing their doctoral degree. That is not to say that someone deciding to leave a graduate degree program is lesser; the focus here is not on the outcome, but rather the events. Rather than giving into their negative self-talk, Naomi leaned into their friendship, and together, Naomi was able to begin the shift back towards their true self: chosen, happy, smart, energetic, driven, loved, and powerful.

what brought you to this research project?

white men: idk I was interested

women of color: after generations of senseless structural oppression I needed to find language to name my situation and will not rest until I have an answer

Figure 4-6. Text replicated from the image under the Otherness & Whiteness theme (sourced from a deidentified twitter post).

The sub-theme of ***otherness and Whiteness*** was first discussed by Erik in the focus group interview in response to their image in Figure 4-6. Erik shares the context for this image, and how the predominately White male space of engineering (Riley, 2003) has pushed the ideal of objectivity and separation of personal values from the work engineers do. He said:

> On this theme of whiteness, particularly in engineering, part of the reason that I'd included this image, is that I'd actually had almost this exact same conversation with one of my best friends in [geographical location] who identifies as a woman of color. So this basically is what our conversation looked like, but I also think is pretty typical of what engineering is in general. With engineering being this predominantly White,

> predominantly male space, I don't think most of the people working on research projects have any personal investment in the outcomes. They're just like, ‘I'm doing this, it's science.’ And then you have people, especially women of color, coming in and being like, ‘I'm doing this because it's very personal to me,’ it's almost like [they are ridiculed]. It's like <sarcastically>, what are you bringing your personal... clearly you're supposed to separate you as an individual from the work that you're doing. Which of course is completely ludicrous, but that's the dominant culture in engineering.

Erik highlighted an important distinction between values shared by those with dominant voices in engineering (i.e., continuing generation White males), and those who are minoritized within the space. Echoed in literature, there is often a dominate narrative that an engineer’s work is based in math and science, is inherently objective, and therefore free from social bias (Godfrey & Parker, 2010; Riley, 2003). Erik in fact shared in this experience, electing the research they studied based on their interest in the science of the work. I argue that Erik’s experiences are part of the larger norms within engineering and STEM fields. Yet, in contrast, women and other minoritized individuals’ interest in science is strongly tied to altruistic and communal values (e.g., helping others; Carlone & Johnson, 2007; Diekman et al., 2015). Furthermore, recruitment efforts into STEM for minoritized individuals have focused on highlighting the potential of STEM degrees to aid in altruistic goals without reconciling the ways this viewpoint directly conflicts with the dominant view of objectivity (Diekman et al., 2015). That is, minoritized students are often recruited and/or motivated to join engineering from a desire to help others and give back to their communities. However, once in engineering, students are told that their personal motivations and goals have no place within engineering, and therefore should not factor into the work they do and choices they make (Cech, 2014). These differences in how minoritized students are recruited into engineering could factor into these students' feeling othered.

Differing motivations for pursuing a graduate degree in engineering is only one factor that can contribute to these feelings. Similarly, Naomi shares their own experiences within engineering as a person of color. She said:

> I think I definitely resonate with that, going I guess to a school like [school] and definitely feeling like the other, because it's very painfully obvious, it's like, 'Which of these [people] do not belong?' So I feel like I stick out like a sore thumb in all my classes and basically any space I go to. And it is uncomfortable, so it's like that coupled with this idea of having to do, you know, like research and being overwhelmed by the work I need to do. It also contributes to that isolation. … Then also adding the, if you will, the racial element to it. So before, where I would be walking on campus and feeling very conscious in my skin, now, I can, I guess exist on an online forum and not feel like I stand out. It takes away that. So I definitely feel conflicted about [the] online school thing, because in some ways it definitely has been harder, but in other ways it has been better.

As Naomi discussed, being a non-White student in engineering at a historically White institution, they felt hyper-visible and uncomfortable. Naomi did not feel alone in this. In their individual interview, Adrian shared their gratitude for being able to distance themselves from those causing them harm during the pandemic. They said:

> Oh, yeah, no. I mean, it didn't at all. Honestly, the pandemic has been helpful in that sense, because I don't see any of these fucking people. Part of the reason why I was very hesitant to, because I had heard other people, pretty much queer bashing happening. I was like, I'm putting up [with] a lot of shit already. I don't need more. I can keep doing,

> covering and passing strategies that I do and whatever. I don't need people to be in my business in that way. If it is that I do, I will be the one that invites them in. Literally having the social distancing away from these people has helped tremendously. I don't have to deal with it. Right? I can literally just check the fuck out. It's - I'm not forced to remain in this space.

Adrian shared how it took a literal pandemic to provide them the space and boundaries to allow them to focus on the other aspects of their lives and degree as a queer person. Adrian and Naomi shared that the frequency and impact of discrimination confronted was reduced due to the virtual nature of the pandemic. Research on engineering graduate students has demonstrated that students with minoritized identities confront additional barriers in pursuit of their studies. For example, Black engineering graduate students are told in overt and covert ways that they are not expected to succeed within engineering and that they do not belong (Bork & Mondisa, 2022; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). Furthermore, the coping mechanisms students use to persist in these spaces impact not only their academic success, but also their mental and physical wellbeing (Bork & Mondisa, 2022; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Stallman et al., 2021; Torres et al., 2010). With the virtual format, potentially harmful interactions with peers, advisors, and other members of the institution were (on average) reduced. This is because all levels of interaction in a virtual environment required additional planning and/or intentionality (i.e., removed unplanned meetings and bump-ins with individuals). Furthermore, virtual meetings allowed for degree of anonymity (e.g., ability to turn-off camera, participate under an alias, etc.). Therefore, it is not surprising that switching to an online format reduced these negative experiences.

4.5.4.2 Quarantine Life

The theme of ***quarantine life*** was defined as aspects of living and adapting to life during the coronavirus pandemic (Covid-19). This theme centers on the quarantine life image grouping, as presented in Figure 4-7. As hinted at in the identities theme, participants with minoritized

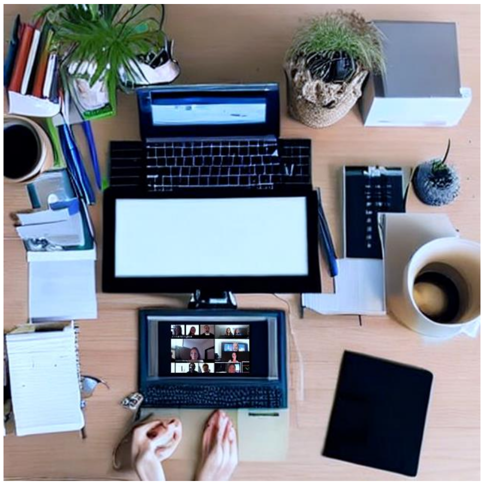

Figure 4-7. Image from the theme Quarantine Life (note replaced, original online version at Green Queen, 2021).

identities felt relief with the switch to a virtual graduate school experience as they were no longer subjected to harmful spaces and/or hyper-visible in those spaces. Others had more prominent negative experiences. Aiden shared their graduate school experiences during the pandemic in both the focus group and individual interview. He said:

> I had momentum from undergrad finishing strong and I was... powered through the first half of the semester and then it started kicking in. And then as [graduate school] phased into full research after the concentrated classes, combined with COVID, that just really amplified the isolation and sense that I have no idea or what I'm supposed to be doing . . . I wouldn't knowingly choose to do grad school during the pandemic. Of course nobody

> could predict that. That's been very isolating and I think taking a lot of the joy out of research and thinking where you can present smaller updates at a much higher frequency when you're in an office with people. And we never really replicated that through email or Slack. Even virtual webinars are not as fun as actually going in person . . . I didn't really portray [becoming a candidate] in any of the images [I provided] because it was muted by not actually being able to celebrate with friends. So it's just another... not a real celebration. Just like, a Zoom call. Doesn't feel like anything actually happened.

As Aiden reflected on their experiences switching from undergraduate to graduate school, he must adapt to the new expectations and norms of school; whereas undergrad experiences may relate to coursework and social organization, graduate students tend to focus on research and communicating their career aspirations (Wyatt & Oswalt, 2013). However, for Aiden, it was difficult to separate this transition from the onset of Covid-19. They remark that they would have never taken this route knowing that they would be doing most of their degree during a pandemic. More specifically, the switch to virtual interactions hindered their happiness in graduate school, from conducting and sharing research to completing academic milestones (i.e., achieving candidacy).

In their individual interview, Nitya echoed feelings of isolation as an international student being in the U.S. and living on their own for the first time:

> I guess the Covid-19 situation is pretty bad. ... For one, I couldn't go back home. I couldn't fly back to [home country] and I was really looking forward to that, or having my parents attend my graduation, which I didn't. But also, I feel like I missed out on the university experience because all my classes were virtual. I missed going to classes and being able to take advantage of all the resources that the university had to offer.

With the pandemic, Nitya shared feelings of frustration in not getting the graduate school experience they had sought out in addition to having missed out on all the resources and opportunities that come with an in-person experience. Zoey elaborated on this by discussing how the virtual format and move to working from home negatively impacted their graduate school experience:

> I think the virtual aspect, especially as someone who has [a] completely computational project, has made a lot of the more negative emotions stronger and also hurt my work/life balance … I definitely also relate to having those thoughts and self-doubts a lot. I think especially during COVID because I've been working from home, so I don't have very much feedback or anything as much. But one thing I've done to combat that is really just talking to other people in the lab. Once I get past that fear of saying how I'm feeling, really doubting or being confused, I think other lab mates tend to be more approachable to me than my advisor every time. So I think just being able to talk to my other lab mates, because they're going through the same thing, has helped me a lot.

Zoey shares how being a researcher who primarily works from their computer and therefore could work from home during the pandemic felt like a negative shift in work-life balance and increased feelings of doubt. However, Zoey found ways to cope with some of these aspects and adapt to the virtual experience by leveraging near-peer mentoring. By talking to peers for support in their struggles, Zoey was able to validate their experiences and get some support they needed to progress in their studies. These findings are not surprising. In a 2018 study, Posselt found that overall, graduate students view their advisor as a final option for seeking emotional support out of fear of being stigmatized or dismissed. This also seemed to ring true for Aiden, who shared in their individual interview how they were able to find support pre-pandemic:

> During a lunch break or to meet people, or in the afternoon, late afternoon, I'd often go down the long hallway to try to bump into people and catch up … or if anyone's working on homework that I can join in on … For a while, we would have a cohort virtual lunch, because most days [pre-covid] we would have a decent sized group go to the cafeteria and have lunch between the morning and afternoon classes. And for a good number of months that kept up, but then it petered off.

Pre-covid, there were opportunities for students to ask for help from others in a low-stakes way. For Aiden, there was a near-peer community that existed that tried to adapt to a virtual format. However, and as expressed by many participants, this was not sustainable. The decrease in social interactions, and therefore, opportunities to seek help, contributed to participants' mental health experiences.

4.5.4.3 Mental Health

The mental health theme encompasses anything related to an individual's affective state and/or impacting their emotional or mental state. This theme includes two of the image groupings, ***isolated and singled out*** and ***overwhelmed and unsure***, as depicted in Figure 4-8 and Figure 4-9, respectively.

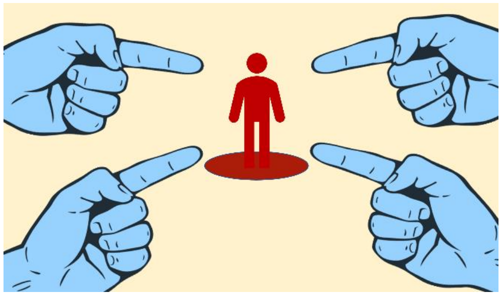

Figure 4-8. Image from the theme Isolated & Singled Out (note replaced, original online version at Milken Institute School of Public Health, 2021).

From previous themes, the theme ***isolated and singled out*** was also present, including feeling othered within students' programs and institutions and from changes brought on by Covid-19. At the core of the theme of isolated and singled out is the notion that as a graduate student, you are supposed to figure out everything on your own. Naomi begins by sharing their experiences:

> The whole [feelings of isolation] that came to mind was entering grad school and thinking... or with just expectations, that, 'Oh, undergrad did not prepare me for this,' and then having that thought double down when... So I've had a couple of advisors over the years, and the first advisor basically saying... basically reiterating this thought that was in my head that, 'Oh, I should have come in knowing, [come in] with this knowledge to do my research.' And basically, being dissatisfied with the fundamentals of what I was bringing in. So yeah, just this feeling of overwhelmingness, this feeling of isolation, this, 'Oh, this is terrible.'

Naomi shared how they have not only felt that their undergraduate education was insufficient to prepare them for graduate school, but that their first advisor echoed these sentiments. In their individual interview, Naomi shared how they had struggled meeting milestones in the program, and therefore decided to leave their first program. Statistically, over half of doctoral students do not complete their degrees (Sowell, 2010). Furthermore, literature has detailed that the student-advisor relationship strongly impacts engineering graduate students' intentions to persist (Berdanier et al., 2020; Bork & Mondisa, 2022). It is therefore unsurprising that Naomi was not the only participant to have changed advisors. Unlike Naomi, however, Alex felt supported in both advising relationships. At the same time, Alex resonated with feeling isolated and singled out:

> Similar to Naomi, I've also had multiple advisors in grad school now, and both of whom I

> uniquely loved working for but for various reasons I switched. And what's interesting is, while I've had such supportive and great and pretty awesome advisors, I still have these feelings, I still have these feelings of isolation. I still have these feelings of self-doubt and not feeling good enough and I don't know what I'm doing. I just find that very interesting that, even though I have a lot of support, I would consider, sometimes I still just get into my own head about what I am capable of and like that fear of … you know not being able to do my best or fail or whatever just because you know just there.

As with Naomi, Alex reflects on feelings of imposter syndrome during their time acclimating to graduate school despite feeling very supported during the process. To help understand what might be causing this, Zoey shared their experiences:

> I would just echo what [was] said, because for me coming to grad school, this is the most... at least in my lab, everyone works on pretty independent projects and it was definitely overwhelming to feel like you're the sole person responsible for your entire project. And that feeling of isolation, of not knowing sometimes even where to get help, as far as research goes. So I can relate to that too . . . I would just think there's an expectation that you'll be able to teach yourself everything. There's a lot of self figuring out, which takes a large amount of adjustment, I think, coming from undergrad.

Zoey shares how they understand these feelings of isolation as someone who does independent research projects. That is, having to be responsible for the progress and direction of a project without yet having either learned or developed confidence as an independent researcher made them feel isolated and overwhelmed. Doctoral graduate students are expected to develop into independent thinkers capable of conducting self-guided research (Wyatt & Oswalt, 2013). Furthermore, it is the role of graduate students’ advisors to help their students develop these skills, and as with any relationship, misalignment can occur, including differences in communication norms, preferred management style, and research interests (Bork & Mondisa, 2022). However, students' perceptions and expectations on what graduate school is could contribute to misalignment within the advising relationship.

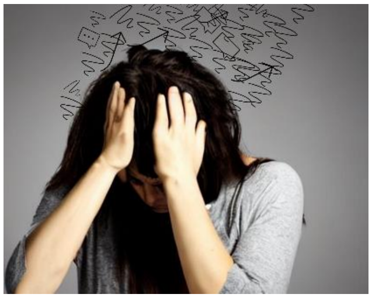


Figure 4-9. Images from the theme Overwhelmed & Unsure (note, both replaced, original online versions at AACSB, 2021; Sonic Reset Therapy, 2021).

Although related, the sub-theme of ***overwhelmed and unsure*** was made distinct by the participants. Alex shared what this difference was:

> I fully agree with what everyone has said to describe those photos, but I guess another layer for me that I thought described some of my experiences was [this] constant fear, especially my first semester, of just constantly feeling overwhelmed and [I] just didn't know what exactly... I didn't really feel prepared... I felt prepared for grad school and yet not at all at the same time. There was so much I had to navigate, so much I didn't understand, so much that I just wasn't prepared for, especially because I didn't have an experience of doing undergrad research, except in my last semester and it wasn't that involved.

Alex shared how their feelings (overwhelmed and unsure) were rooted in a constant fear and anxiety of not being able to complete their work. Furthermore, they link these feelings to feeling isolated and singled out as someone who did not have previous experiences with independent research, and therefore missing out on experiences that would have helped combat these feelings. Naomi echoes experiences of feeling overwhelmed and unsure with their own:

> I also relate to that experience of … like having to work with this high expectation, I don't know if those are the right words I'm trying to use, we're looking for, but kind of like being in an environment, especially in the lab, where other people in the lab seem to also be very... have high expectations. So coming in as a first year student and having to navigate through such expectations can be very daunting initially and can be hard to work through if the right mentorship is not found. And certainly, I did struggle the first several years, and it wasn't until later I was able to find better mentorship to help me get through subsequent years.

Naomi shares how feeling overwhelmed came from not being able to keep up with the "high" expectations set on them by members of their own lab. This was then compounded by feeling unsure what to do to meet these expectations. Naomi again highlights the importance of the student-advisor relationship is for students' success.

Aiden related to this, sharing their own experiences navigating their student-advisor relationship. He said:

> I can, I relate to that. And I'm thinking of the question [mark image], because I can think of some specific instances where my advisor has had my back and people in the lab also had similar cases. But I also feel like, when I'm stuck, it's like- that's the best time to go for help, for your advisor, but that's when I'm feeling stuck and down and whatever, that's like... something is, like I have to get over some barrier to actually go talk to my advisor.

> And I'm trying to think, what would be the amount of support that would cancel out these negative thoughts, and it's like, 'Hmm.'

Here, Aiden highlights another important aspect of the relationship that was echoed by Alex previously. As shared previously, even if a student believes their advisor supports them and is willing to help them, faculty are viewed as a last resort for seeking help (Posselt, 2018). Fear of being stigmatized and discriminated against are real. In addition to race- and gender-based discrimination, students with disabilities often fear disclosing this (e.g., unaccepting, hostile; Zongrone et al., 2021).

Fear of being stigmatized and being discriminated against were also present in the experiences Adrian shared in their individual interview:

> I have had a number of friends leave engineering because of mental health issues, that honestly, they talked about an administrator as actively provoking through a lot of just meritocratic framings of 'if you're not doing well here, it's your own fault.' Generally, that line of push out, that's what it is, right? It's this process where an engineer is only considered [to be] this thing, and if you're not doing this work, you're not doing engineering. Why the fuck are you here? Right?

Adrian's second-hand accounts detail how some students were made to feel not good enough for engineering when interacting with administrators. Specifically, administrators would use a meritocratic framing, or the view that an individual's success within engineering comes solely from their effort and hard work as engineering is fair and just (Cech, 2014). Administrators use this narrative to focus the blame of students' problems to be as result of their own personal failings. Adrian shares how these actions were directly cited by students' to contributing to their mental health concerns and reasons for leaving their studies. Furthermore, these actions are known to contribute to negative stigma for seeking help for mental health concerns within engineering. Zongrone et al. (2021) found that individuals with non-apparent disabilities (e.g., non-visible, which includes mental health and learning disabilities) often found themselves not being believed, requiring them to advocate for themselves and navigate potentially hostile conversations with faculty and staff.

4.5.4.4 Support Structures

The support structures theme was defined as relating to an individuals' network of individuals they can turn to in a time of need. This theme included the ***external supports*** sub-theme, with the images for this grouping included in Figure 4-10.

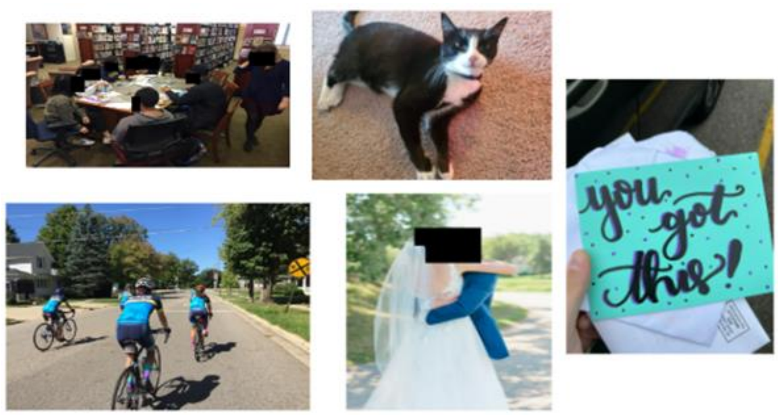

Figure 4-10. Images from the theme external supports.

To begin, I go to Erik's experiences of navigating the culture of engineering shared in his individual interview:

> I would say that it's very much like you build support networks with your friends and that's how you survive. ... you're going to build your support network just to survive whatever your classes are, survive your program. Although there's also kind of like, if

> your friends are doing well, you also don't necessarily want to show that you're struggling. It's either you're all struggling or you're all pretending to be okay.

Although referring to their experiences in undergrad, Erik commented how this strategy of building a network of friends to survive their program carried over to graduate school. However, as opposed to friendships that existed within the academic setting, the interactions "*were happening outside of the department.*" The justification for these external supports was synthesized by Naomi:

> Trying to cope with the criticism, the self-isolation, and then trying to combat this with self-affirmations and things like that, another form of support is external. So I'm seeing a lot of pictures of, I guess, group work, if you will. There's also some signs of friendship happening . . . I'm seeing a lot of relationships. I see what appears to be a wedding photo . . . I see two cats, which, yes. Yeah, so it sounds like there's a lot of external support also to help us navigate through grad school.

Having support outside of the graduate school experience was necessary to help participants cope with the intense negative emotions invoked when doing an engineering graduate degree. This was also echoed in Diana's individual interview. She said:

> Last year during COVID, I spent some time away from [school and went] home. This was kind of when I was in the thick of some of the emotional stuff that I was going through, and I was contemplating leaving my current advisor for another advisor relationship. And this painting I guess just represents maybe some of the things I did to de-stress or relax with family. And yeah, I think it was impactful too, because I got to process through things by talking with others. And I know people really validated what I

> was feeling. I think other grad students, easy to kind of internalize these things. And okay, there must be something I'm doing wrong. And I still struggle with that, honestly.

Whereas Naomi explained why these relationships and external supports are important, Diana highlights how they use these relationships to cope. By being able to participate in an art activity physically separated from the source of stress and in an environment they felt safe, Diana was able to mentally unload and have their feelings validated. This is supported by literature, in which engineering graduate students' needs to feel supported and validated on a human level throughout the challenging process of graduate school (Bork & Mondisa, 2022).

4.5.4.5 Activities

The theme activities was defined as something done by a person or group, and encompassed two of the focus group interview image groupings, ***milestones*** and ***new experiences***, presented in Figure 4-11 and Figure 4-12, respectively.

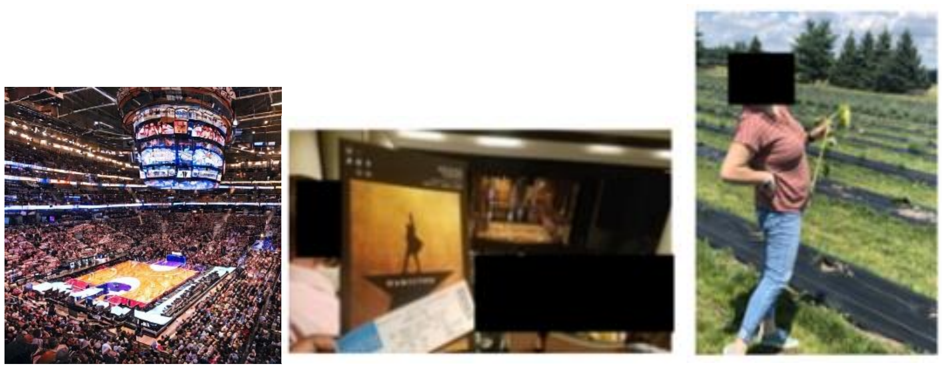

Figure 4-11. Images from the theme New Experiences (note, left image replaced, original version online at Destination [redacted], 2021).

Almost every participant discussed entering graduate school as a ***new experience***. For Nitya, however, there was unique duress being an international student living on their own for the first time in addition to being in a different country. Nitya shared what their experience was for their first semester in their individual interview:

> My first semester here, I was having a lot of trouble with one of my courses and I felt really bad because up till then, I never had any problems studying or doing well in a course. I had … I remember we'd go volunteer, everyone was always doing much better than me. I didn't know. I felt really stupid and then I started missing my family, I was homesick. It's all getting bundled together and I'd feel like cutting myself off from everything and then I'd isolate myself and sit and stare at the wall or something like that . . . I could talk as much as I'd like [to my family] but I didn't want to worry them, so I never really said much about how I was feeling.

As shared, Nitya began comparing their struggles to their perceptions of others, which then compounded on their feelings of isolation and separation from their major external supports. This then turned into an overwhelming feeling that Nitya described as preventing them from seeking help from others. International students often confront additional barriers when transitioning into their studies (e.g., acculturative stress, financial stress, etc.); furthermore, there are cultural differences in how international students seek help, such as turning to their friends and families over seeking help from a mental health professional (Bork & Mondisa, 2022; Hyun et al., 2007; Li & Stodolska, 2006; Liao & Wei, 2014; Mikal et al., 2015; Rice et al., 2012; Zhou, 2014).

Several intense and negative new experiences were shared by other participants as previously discussed. At the same time, not all new experiences were negative. Participants also shared their positive experiences since starting graduate school. Alex shared:

> I feel like there's so many people, so many things I just would not have experienced if I didn't come to grad school. And obviously with the pandemic it was very hard... because I just finished my second year, so people I was friends with [in] my first year, who were master’s students, graduated. So I was losing some friends and then it was hard to make

> friends during the pandemic. And now that vaccinations are more widely available and people are more safely able to gather. So other groups that I've been virtually keeping up with during the pandemic are now safely meeting in person and we're making plans to go do trips and go to [nearby geographical location] or go explore more parts of [state], or just hanging out and having a movie night. And just I guess having those things that also bring you joy during grad school in order to balance it out.

Alex shares this notion of balance. That is, although there were negative experiences, there were also positive ones. Erik built on this, he said:

> That's very similar to the cool, new experiences, doing things other than graduate school. Because it's good to do things other than just research, teaching, and your other responsibilities. So definitely before coming to [school], which is a big public institution, [I] hadn't had the opportunity to go to, really, live sporting events at all with any regularity, especially at that size. So that's been a lot of fun.

Erik shared the ability to attend large sporting events as something they have not had the chance to do before. For both Alex and Eric, these new experiences served as positive relaxing coping mechanisms that fulfilled interests outside of graduate school (Sallai & Berdanier, 2022; Stallman et al., 2021).

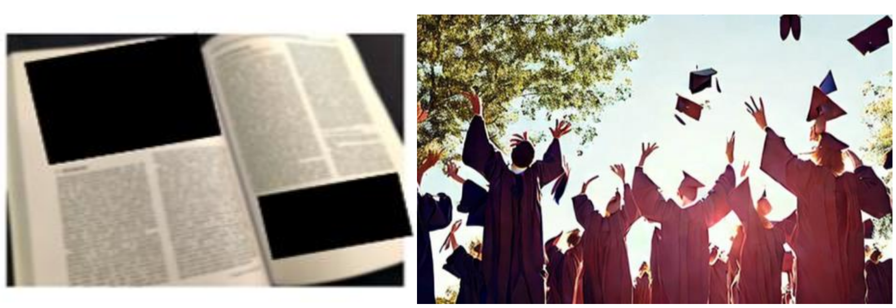

Figure 4-12. Images from the theme Milestones (note, right image replaced, original found online at Skynesher, 2021).

Finally, all participants discussed their ***milestones*** throughout their academic experiences. As discussed above, some of these milestones were muted due to Covid-19, and not all milestones that occurred for participants were focused on their academics. For this paper, I focus on academic milestones. As discussed by Diana previously, some milestones were incredibly positive and affirming. Diana shared how they felt a sense of accomplishment when they were able to work over an academic seasonal break to "*[figure] something out that I hadn't noticed before. And I think that really helped to build my confidence as a researcher to... finally putting things together.*" Aiden shared a similar experience with one of their images:

> This image was trying to capture a group of people working around... on homework in a study room [earlier in my program] and finally figuring out how to do the problem … [and] the highs of, "Oh, I just figured something out," [that occurred] at least, in the first year or so, with other people working on [homework] in a class or something.

Working with others to solve a difficult homework problem was a positive academic milestone for Aiden. They expanded on this in their individual interview, sharing how this collaboration with others was sometimes the only way to make progress:

> I just remember various nights where the only way to move forward on homework was to go to office hours or talk to someone or possibly read a lot in the library, which sometimes I wouldn't have [the] chance to at this point. At some point I had to figure out when to cut my losses and go to sleep so I could wake up for the early class in the morning.

This ability to work collectively on a difficult task highlights how Aiden was able to navigate some of the uncertainty to progress in their program. In their individual interview, Erik shared a similar experience where finding a community helped provide direction during both a new experience as well as a milestone:

> One of them was the first article that I had published, which actually was printed in print, so I have the physical copy of it. And part of the story of that article, in particular, was there's a [workshop conference] where many of the researchers in my field [participate in] … you submit a paper, they all get together, you workshop the paper. But a lot of it... It's a weekend of fairly intimate networking, there's only like 50 to 100 people there. And so prior to participating in that, this was the summer after my second year, it was like, 'Oh, these are the other people in my field.' Because at that point, [advisor]'s like, 'Oh, do you want to potentially stay in academia?' But I hadn't committed yet because when I came in, not expecting to do a PhD to begin with, it was like, 'Oh, I'll do this and then go be a practitioner.' But that was the point where I actually started to meet the people in the field and be like, 'Oh, this is a community that resonates with me that I want to be a part of so maybe I should stay in academia.' So that's partially what this paper represents for me. It's not just like, "Okay, cool. I published a paper." Which to be perfectly honest, I don't celebrate my publishing victories nearly as much as I should. I'm very much like, 'Okay, cool. That got published. I guess, onto the next one now,' which is not a healthy behavior, but we'll get there eventually. But yeah, it was like, 'Okay, these people are pretty cool. I could get behind seeing them once a year at various conferences and stuff for the next 50 years.'

For Erik, the milestone of their first publication was overshadowed by the community they found to workshop their paper and the larger realization that they wanted to be a part of that community post-graduation. Post-graduate career paths were a large source of uncertainty for most participants, including Zoey, "*when I put the question mark [image], I was definitely also thinking about post-grad plans*." Therefore, understandably for Erik, discovering the path they wanted to take after graduation was a large, positive milestone.

Finally, the act of graduation itself was a milestone Nitya shared in their individual interview:

> I was looking for a graduation photo, actually, and I couldn't find one. But that was another one I was considering, my master's graduation. ... That was actually, I think, the same year I finished my [academic milestone] so that same, around the same time period. ... My family came down, which was nice. I enjoyed ... I don't know, it was just nice. I wasn't expecting to feel like it was an accomplishment, but it did. And that's just a personal thing. Sometimes I don't take in ... Hey, I did well in this. But it was nice to be a family and celebrate.

Although graduating with their master's degree did not first feel like an accomplishment, celebrating this milestone with their family transformed this into a very positive experience for Nitya. For most of the participants in this study, a major goal was to obtain their degree(s) and secure the credentials they needed for the job they wanted. As put by Erik: "*So literally the only thing that I knew about graduate school was I need to go do this thing later to become like a quote-unquote 'real engineer' and get an engineering job if that's actually what I want to do.*"

4.5.4.6 Connecting the themes from the Focus Group Interview

Participants collectively defined eight groupings of shared experiences that fell into five of the six themes from data analysis: activities, identities, mental health and emotional experiences, quarantine life, and support structures (i.e., all but culture). Students' mental health experiences ranged from positive to negative to mixed (i.e., both positive and negative). Although the groupings fell under different themes, the themes are interconnected, relating and building off one another. These findings suggest that these themes are connected as they are related to if and/or how students seek help to cope with stressors during their graduate studies. Although many coping mechanisms can be positive, some coping mechanisms can cause unintended and unwanted negative consequences (e.g., physical, psychological, social, etc.; Stallman et al., 2021). Stallman suggested a continuum of healthy and unhealthy coping strategies, detailed in Figure 4-13 (2021). Healthy coping strategies range from lower intensity (e.g., positive self-talk) to higher intensity (e.g., being receptive to help from professionals) whereas unhealthy coping strategies range from lower harm (e.g., negative self-talk) to higher harm (e.g., help seeking initiated because of suicidal ideation; Stallman et al., 2021).

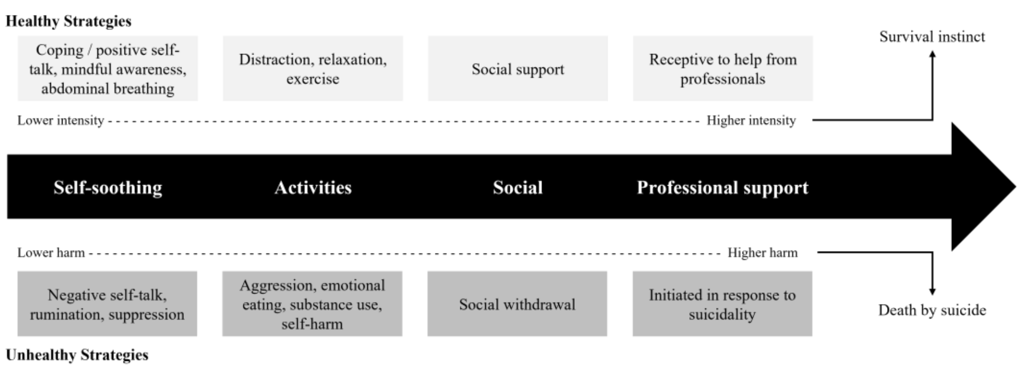

Figure 4-13. Continuum of coping mechanisms, modified from Stallman et al. (2021)

For example, Alex, Diana, and Naomi encountered difficulties in their studies (e.g., their advising relationship, feeling unprepared for graduate school, etc.) that resulted in negative mental health experiences (e.g., isolated, overwhelmed, etc.). Some students even expressed using unhealthy coping mechanisms in response to these experiences (e.g., negative-self talk, social withdrawal, etc.). However, Alex, Diana, and Naomi also communicated using healthy coping mechanisms, such as positive self-talk (e.g., countering negative comments) and activities (e.g., painting, exercise, going to see a play) with social supports (e.g., friends, family) led to positive mental health experiences, including resting, decreasing levels of stress, and increasing confidence in themselves.

Aiden, Erik, Nitya, and Zoey also expressed positive mental health experiences using social support as a healthy coping mechanism. For Aiden, Erik, and Zoey, social support helped them overcome feelings of uncertainty within their future career direction (e.g., increasing their sense of belonging to the community within their research field, helping navigate program milestones, etc.). Nitya, on the other hand, as an international student, commented on how their support system with their family was not accessible for them as they were in a different country. These new experiences for Nitya resulted in feeling homesick and isolated. They shared how they engaged in unhealthy coping mechanisms (e.g., negative self-talk, social withdrawal, etc.) from losing their social supports. Furthermore, Aiden, Erik, Nitya, and Zoey all commented on how the quarantine during the coronavirus pandemic limited their access to social support. Although some have had other supports they could lean into during these times (e.g., spouse, religion, friends, etc.), all comment on the increased social withdrawal.

At the same time, the coronavirus pandemic led to positive mental health experiences. Adrian and Naomi shared how pre-pandemic quarantine, they felt their identities as non-White non-male engineering graduate students made them feel othered and singled out, and that this resulted in negative mental health experiences. However, with the onset of the pandemic, Adrian and Naomi shared how the switch to virtual learning environments mitigated these experiences, and any associated coping mechanisms previously required from engaging in these spaces.

These findings suggest that students' positive mental health experiences may be related to experiences where they are leveraging healthy coping mechanisms and that negative mental health experiences may be the result of not being able to use preferred healthy coping mechanisms and/or from using unhealthy coping mechanisms.

4.5.5 Highlights from Participant Profiles

This section gives highlights of the data contained in the participant profiles and used in the cross-case comparison analysis to answer the section research question. Table 4-12 provides a breakdown of this data by system level of Bronfenbrenner's EST. That is, the EST system level(s) the data came from in the participant profiles for each dimension (and theme) within CEEF was tracked and recorded in this table. In constructing the profiles, two systems were broken into categories based on the system definitions: microsystem was broken into activities and roles/interpersonal relationships, and the chronosystem was broken into individual and environmental transitions. Figure 4-14 provides a visualization of this information at the CEEF

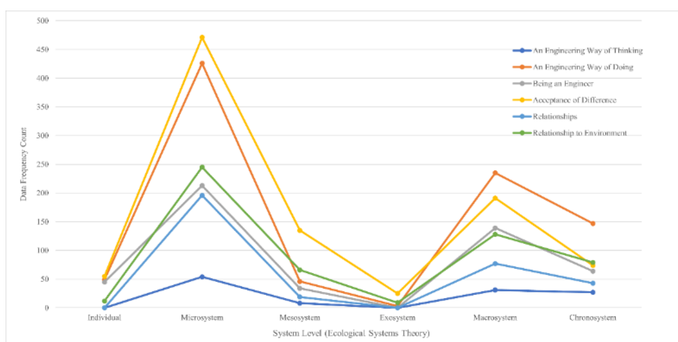

Figure 4-14. Breakdown of data used within the cross-case comparison analysis. Detailing the dimensions in CEEF by the EST system level(s) the data came from (in the participant profiles).

Dimension level. As detailed, a large portion of the data came from the microsystem level, followed by the macrosystem, chronosystem, mesosystem, individual, and then exosystem. This indicates that most of the mental health experiences participants discussed came from their direct environment and social and cultural views, which is in alignment with the data collection

Table 4-12. Distribution of participant data based on EST's system levels and dimension/theme of CEEF

Dimension (CEEF)	Theme	Individual	Microsystem (Activities)	Microsystem (Roles & Relationships)	Mesosystem	Exosystem	Macrosystem	Chronosystem (Individual)	Chronosystem (Environment)
An Engineering Way of Thinking	Math is infallible, innocent, and/or pure	-	1	2	1	-	2	-	-
	Strong prevalence of visual communication	-	6	4	1	-	5	2	3
	Problem solving and design	-	11	9	-	-	9	5	6
	"Best" not "right" answers	-	5	10	3	-	11	10	-
	Objectiveness in math and science	-	2	4	3	-	4	-	1
An Engineering Way of Doing	Hardness	44	74	72	16	2	68	32	21
	Take it	1	54	88	26	1	88	29	12
	Approach problem solving using a toolkit	-	10	11	1	-	8	3	2
	Professional development is conditionally valued	-	2	2	-	-	10	-	-
	Cooperation and competition	-	7	21	3	-	6	-	3
	Education is used for credentials	4	4	7	-	-	14	10	1
	Time is a resource to be managed	-	34	40	-	-	41	25	9
Being an Engineer	"Can-do" attitude	-	4	6	-	-	2	-	1
	Think in bullet points	-	2	3	-	-	8	2	-
	Stereotypes	44	47	49	24	-	67	18	7
	All or nothing	-	35	31	8	-	42	12	7
	Being one of the "guys"	1	6	8	0	-	8	3	2
	Pride in being an engineer	-	12	10	2	-	12	8	4
Acceptance of Difference	Homogeneity	47	42	162	65	8	97	26	4
	Conditional acceptance	8	21	118	50	8	44	11	5
	First impressions	-	13	53	10	8	26	8	3
	Prove yourself	-	33	29	10	1	24	11	6
Relationships	Collaborative	-	18	42	6	-	24	5	15
	Mates	-	9	53	-	-	15	2	7
	Student – faculty interactions	-	24	50	13	-	38	12	2
Relationship to Environment	Situated within several embedded ecosystems	12	33	142	52	9	78	33	13
	Desire for autonomy and independence	-	20	29	13	-	43	11	6
	Inherent oversight	-	8	13	1	-	7	5	11

methods (i.e., interview protocol and surveys).

4.5.6 The Culture of Engineering in Engineering Perpetuates Largely Negative Mental Health Experiences

This section discusses findings to answer the second research question, how does the culture of engineering influence the mental health experiences of engineering graduate students at a historically White institution (HWI)?

I first provide an overview of participants' mental health experiences with respect to the culture of engineering. To do so, I examined the distribution of data in the cross-case analysis with respect to CEEF and present these findings before overviewing the aggregate heat map of mental health experiences with regards to the culture of engineering, as operationalized by the dimensions and themes of CEEF. I then discuss the findings from the cross-case analysis, focusing on participants' mental health experiences respective to each dimension (and respective themes) of CEEF. I do so by first describing students' responses to a theme (or group of themes) within the dimension, accompanied by the respective dimension's heat map. I then provide an exemplary quote that demonstrates the theme(s) just discussed. The quote and respective theme(s) are then connected back to relevant literature. This process is repeated until all the themes within a dimension are discussed. As a reminder, Table 4-8, discussed previously, details the color key for these heat maps.

4.5.6.1 Overview

When examining the distribution of data in the cross-case analysis across the dimensions and themes of CEEF, I found that every participant touched on every theme of CEEF (as detailed in

Table 4-13). That is, every participant was represented in each of the six dimensions of CEEF. Of the 28 themes, Aiden and Alex were represented in 27, Erik and Naomi were represented in 25, Diana and Zoey were represented in 24, Adrian was represented in 23, and Nitya was represented in 20. Table 4-14 details the heat map for the dimension theme levels by participant. On average, experiences in the *An Engineering Way of Thinking*, *An Engineering Way of Doing*, and *Relationship to Environment* dimensions were negative. Experiences in the dimensions *Being an Engineer* and *Acceptance of Difference* were mixed whereas the dimension *Acceptance of Difference* had mixed or positive experiences, on average.

On average, the theme pride in being an engineer had positive mental health experiences for over half of the participants. There were also pockets across nine themes where some participants had positive mental health experiences: strong prevalence of visual communication, approach problem solving using a toolkit, cooperation and competition, education is used for credentials, think in bullet points, first impressions, mates, and student – faculty interactions. However, in each of these nine themes there were also students who had negative mental health experiences. Furthermore, for all other themes except for being pride in being an engineer, on average, students had negative mental health experiences. That is, most of the participants' mental health experiences with respect to the culture of engineering were or leaned toward being negative. Furthermore, comparing participant's average mental health experiences, Erik, Naomi, and Aiden had neutral or mixed positive and negative experiences, whereas Adrian, Alex, Diana, Nitya, and Zoey's experiences were skewed negative. The following sections will go into further detail on these findings within each dimension. This will be done by discussing each dimension one by one, overviewing the themes for each dimension and participants' experiences with these

Table 4-13. Detailing prevalence of CEEF themes by participant

Dimension of CEEF	Theme (number of participants)		Participants: Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
An Engineering Way of Thinking	Math is infallible, innocent, and/or pure	(4)	x	x	x	x				
	Strong prevalence of visual communication	(8)	x	x	x	x	x	x	x	x
	Problem solving and design	(7)		x	x	x	x	x	x	x
	“Best” not “right” answers	(7)	x	x	x	x	x	x		x
	Objectiveness in math and science	(4)	x		x		x	x		
An Engineering Way of Doing	Hardness	(8)	x	x	x	x	x	x	x	x
	Take it	(8)	x	x	x	x	x	x	x	x
	Approach problem solving using a toolkit	(5)		x	x	x			x	x
	Professional development is conditionally valued	(4)	x	x	x		x			
	Cooperation and competition	(8)	x	x	x	x	x	x	x	x
	Education is used for credentials	(8)	x	x	x	x	x	x	x	x
	Time is a resource to be managed	(8)	x	x	x	x	x	x	x	x
Being an Engineer	Can-do attitude	(4)		x	x	x		x		
	Think in bullet points	(6)		x	x	x	x	x		x
	Stereotypes	(8)	x	x	x	x	x	x	x	x
	All or nothing	(8)	x	x	x	x	x	x	x	x
	Being one of the “guys”	(4)		x			x	x		x
	Pride in being an engineer	(8)	x	x	x	x	x	x	x	x
Acceptance of Difference	Homogeneity	(8)	x	x	x	x	x	x	x	x
	Conditional acceptance	(8)	x	x	x	x	x	x	x	x
	First impressions	(8)	x	x	x	x	x	x	x	x
	Prove yourself	(8)	x	x	x	x	x	x	x	x
Relationships	Collaborative	(8)	x	x	x	x	x	x	x	x
	Mates	(7)	x	x	x		x	x	x	x
	Student – faculty interactions	(8)	x	x	x	x	x	x	x	x
Relationship to Environment	Situated within several embedded ecosystems	(8)	x	x	x	x	x	x	x	x
	Desire for autonomy and independence	(8)	x	x	x	x	x	x	x	x
	Inherent oversight	(8)	x	x	x	x	x	x	x	x

Table 4-14. Overview of participants' mental health experiences by dimensions of the CEEF framework

Dimension	Theme (number of participants)		Participant								
			Averaged	Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
	Average Overall Experience										
An Engineering Way of Thinking	Math is infallible, innocent, and/or pure	(4)									
	Strong prevalence of visual communication	(8)									
	Problem solving and design	(7)									
	"Best" not "right" answers	(7)									
	Objectiveness in math and science	(4)									
An Engineering Way of Doing	Hardness	(8)									
	Take it	(8)									
	Approach problem solving using a toolkit	(5)									
	Professional development is valued conditionally	(4)									
	Cooperation and competition	(8)									
	Education is used for credentials	(8)									
	Time is a resource to be managed	(8)									
Being an Engineer	"Can-do" attitude	(4)									
	Think in bullet points	(6)									
	Stereotypes	(8)									
	All or nothing	(8)									
	Being one of the "guys"	(4)									
	Pride in being an engineer	(8)									
Acceptance of Difference	Homogeneity	(8)									
	Conditional acceptance	(8)									
	First impressions	(8)									
	Prove yourself	(8)									
Relationships	Collaborative	(8)									
	Mates	(7)									
	Student – faculty interactions	(8)									
Relationship to Environment	Situated within several embedded ecosystems	(8)									
	Desire for autonomy and independence	(8)									
	Inherent oversight	(8)									

themes. As discussed, a heat map dimension will accompany this discussion to provide a visual overview of participants' mental health experiences.

4.5.6.2 An Engineering Way of Thinking

There were five themes under the dimension *An Engineering Way of Thinking*. Across these five themes, there were 17 sub-themes, as detailed in Table 4-15. The first theme was that *math is infallible, innocent, and/or pure*. This theme was defined by the notion that math is reality, it cannot lie or be biased, and that engineers trust in math. Participants' experiences with math being infallible, innocent, and/or pure were negative as this theme removes their personal experiences and emotions from the process of using math.

Another theme was *problem-solving and design*. This was defined by an engineer's thinking and problem-solving. Specifically, that this process is dominated by a reductionist and top-down approach to break complex problems into smaller, tangible components. Design, therefore, is used to practice these skills and apply engineering knowledge. Generally, students had positive experiences problem-solving in the context of their courses. However, outside of these classroom environments, students found a lack of structure and guidance on how to approach problem solving that resulted in negative mental health experiences.

Working to find the "best" not "right" answers was a third theme. This theme was defined by engineer's use of contextual factors to drive the solution to a problem. This includes factoring in external demands, assumptions, and resources that could re-define the best answer if they were to change. Students' experienced frustration with the theme *working to find the "best" not "right" answer.* This was because students working to find the "best" answer had to do so by accounting for many different external environments (e.g., culture of higher education in the U.S. and/or their discipline). In addition, many students' negative experiences stemmed from

Table 4-15. Participants' mental health experiences with the CEEF dimension *An Engineering Way of Thinking*

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Math is infallible, innocent, and/or pure	diversity, equity, and inclusion efforts being discussed mathematically in terms of generating profit	(1)								
	math is reality, and math cannot lie	(1)								
	math is math; it is logical; follow the chain and you will get to the answer	(2)								
Strong prevalence of visual communication	engineers use visuals to communicate beliefs & values	(3)								
	engineers use visuals (sometimes aided by text) to communicate knowledge to other engineers	(5)								
	visual communication is hindered in virtual learning environments	(3)								
Problem solving and design	engineers access resources e.g., books, formulas, defined processes) to help them problem-solve	(7)								
	mental health can be talked about in a problem solving context (e.g., how to address it, ways go about it)	(3)								
	engineers use a reductionist approach and/or assess potential outcomes to solve problems	(3)								
	an engineer's solution may need to account for feedback, input, and/or decisions from other engineers	(4)								
"Best" not "right" answers	the "best" answer may be driven by the culture of academia within the United States	(4)								
	the "best" answer may be driven by the culture of engineering	(4)								
	the "best" answer may be driven by the culture of a student's program/work environment	(4)								
	the "best" answer is reliant on the resources and knowledge a student is constrained by	(6)								
	engineers apply decision making principles to determine the "best" outcome for personal problems	(4)								
Objectiveness in math and science	assumption that all engineers interact with math and science in the same, objective, logical way	(4)								
	assumption that math and science are objective (e.g., race and gender free)	(4)								

situations that lacked adequate resources (e.g., time, support, training, etc.) to achieve the “best” answer.

A negative experience that represents these three themes comes from Diana. Diana discussed a series of negative experiences working to collect data for a research project. They said:

> I was doing a project … it wasn't working, and I felt like I was being blamed for it not working. [My advisor] requested that I just repeat it over and over, and this was like for months, probably two months, probably three months actually, which is a long time to just do the same thing, literally the same thing over and over. And I would explain what I did, and I felt like [my advisor] didn't trust me until another grad student came and did it. And okay, it didn't work, and we tried to evaluate what the reason was. … [I feel it was hard to make my advisor happy] because I'd present data during our meetings, and it'd never be enough. And like no, slow down, you need to repeat this. And at the beginning I was like okay, this was just a phase. I will actually get over this. But that just repeated itself over and over and over again for months, years. ... I finished my fifth year now, and I still don't have data [when I began collecting in my first year], which is very concerning cause I [need this data].

Diana shared how this process of problem solving to get to the “best” answer for collecting data for their research was being overseen by their advisor. Diana expresses how this project was not working. However, Diana’s advisor kept insisting that they run the project again and again despite Diana expressing their concerns that there was an error in the methods being used. This caused Diana to become increasingly frustrated as she was reaching the same conclusions again and again. In this scenario, the “best” answer for Diana given time and resources would be to work with their advisor to understand why the project was not working as intended rather than continue to run the same experiment. It was not until a large time span had passed that Diana's advisor explored another path, bringing in another student who confirmed Diana's results. With two students confirming the project was not working, Diana's advisor finally agreed to explore other possible causes. Diana's experiences demonstrate how a graduate student's resources and possible avenues to solve problems can be strongly tied to their advisor, and how this support (or lack of) impacts a student's mental health experiences. Given that Diana's advisor did not shift to explore other possible causes for the project's repeated failure until another student confirmed Diana's findings, Diana was asked if she believed there were any race or gender-based stereotypes at play in her interactions with her advisor. Diana shared,

> Yeah, you know, I've thought about that. It's hard for me to say. [My advisor] hasn't really said anything like that was racist or that was sexist. I do know [my advisor] does speak to women differently than the men, so that could be it. And I know another student kind of went through a hard time. [The student] ended up leaving the program, and that was a couple years ago, but I'm not sure.

When asked if Diana thought their advisor was interacting with Diana differently because of their race and/or gender, Diana admitted that they had considered this before, and that they know their advisor to talk to women students differently. Therefore, Diana's identity as a Black woman may be tied to these negative mental health experiences. Recent work supports these findings. Engineering programs not designed for minoritized students can create stressful environments where minoritized students feel pressured to overcompensate within these spaces to prevent further perpetuation of negative identity-based stereotypes (McGee & Bentley, 2017). Studies have also demonstrated how Black students within these spaces must confront biases of intellectual inferiority (Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). These findings were evident in Diana's experiences conducting their experiment repeatedly, trying to prove that the problem was coming from the methods and not her skills as a researcher, and only being believed when the method was proved to not work by another student. Furthermore, recent work has detailed how unsupportive and discouraging advisors generate additional sources of stress that harms Black doctoral students, adding to the physical and emotional cost these students must pay to persist within their programs (Bork & Mondisa, 2022; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). This burden was evident in Diana's experiences, not only emotionally but also in the physical time it took Diana to do this research.

Another theme under this dimension was *a strong prevalence of visual communication*. Hinted at by Diana, this theme referred to the work engineers do as definable and measurable, with a dependence on visually communicating knowledge (e.g., graphics, diagrams, etc.). Overall, students enjoy communicating with others visually, and have a negative experience when they are unable to do so. For example, Aiden shared in their interview, "*when I was presenting my candidacy exam and answering the questions from the professors well and doing a good job on that, that was a highlight*," demonstrating that being able to visually present and communicate on their research was a positive experience.

Finally, the fifth theme was *objectiveness with math and science*. This theme was defined by the assumption that the mathematical procedures, scientific processes, and the laws on which problem solutions were based were race and gender free. Therefore, when using math, it is also race and gender free, regardless of methods or user (e.g., problem solving, teaching, or assessment). A consequence of this theme therefore is an assumption that everyone interacts with math and science in the same, logical way, and that as engineers work is based on math and science, the work engineers do is therefore also race and gender free. Adrian, Alex, Erik, and Naomi all had negative experiences with this theme. However, Erik had a mixture of experiences. Personally, Erik has not felt a conflict with their work being assumed to be objective. However, after a conversation with their friend, Erik realized the privilege of this experience. He said:

> My friend, who is a woman of color and fellow researcher in my field, was challenging me to justify why I do the work that I do (when a person of color could do similar work and get the credit instead, for instance). At the time, she and I were both surprised by how much I struggled to answer her questions … [such as] "What brought you to this research?" I'm like, "I don't know. I was interested, I guess." Whereas she's like, "After generations of senseless, structural oppression, I needed to find language to name my situation. I will not rest until I have an answer" … at least thus far, my research has mainly been motivated by curiosity rather than any sort of emotional stake in my potential findings.

Specifically, Erik shared how being a White male within engineering, Erik's curiosity had been the main driving force for his education. This, however, was not the case for his friend, whose motivations to do engineering came from their desire to understand their lived experiences. This is supported by existing literature, which has demonstrated that women of color are often motivated to enter the sciences by altruistic goals (Carlone & Johnson, 2007). This theme of objectivity demonstrates a source of diverging experiences for engineering graduate students. Specifically, students' motivations for doing engineering work are expected to be separate from their personal values, motivations, or interests, and students whose motivations do not follow these norms may have negative mental health experiences.

4.5.6.3 An Engineering Way of Doing

There were seven themes under the dimension *An Engineering Way of Doing*. Across these five themes, there were 25 sub-themes, as detailed in Table 4-16. The first theme, *hardness*, was defined by the assumption that engineering and its curriculum is hard and difficult. That these traits are innate to the discipline, valued, and respected. There is also an acknowledgement that not everyone will be able to succeed given the level of difficulty. For "hardness", on average, participants felt satisfaction and pride after persisting through something challenging. However, most of the time, the theme of *hardness* was associated with negative experiences (e.g., coursework, uncertainty in research, expectations from advisors or instructors, etc.).

The second theme was *take it*. This theme related to the expectation that individuals who enter engineering need to accept the difficulty and endure it, or they are not fit for the field. As a result, learning is equated to suffering and hardship, with a consequence being that enduring and surviving in this environment can lead to a shared sense of pride and achievement for having "made it". Much like the theme of hardness, the theme *take it* corresponded with negative mental health experiences. The major exceptions were positive experiences using coping mechanisms and social supports to endure this cultural norm.

A third theme was that engineer's *approach problem-solving using a toolkit*. This theme focused on engineering students' education, being centered on gaining expert knowledge and a "tool bag" of skills that can then be applied to solve any problem. Participants had a mixture of experiences. A student's access to the needed resources impacted whether they had a positive experience. Furthermore, many students had negative experiences when their advisor or

Table 4-16. Participants' mental health experiences with the CEEF dimension *An Engineering Way of Doing*

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Hardness	engineering is hard	(8)								
	hardness in engineering is enforced by individuals in positions of authority and through other engineering norms	(8)								
	the hardness of engineering depends on a student's knowledge and preparation for the transition into graduate school	(7)								
	persisting through the difficulty of engineering is based solely on a student's individual abilities	(8)								
	persisting through the difficulties of engineering is rewarding	(4)								
	the difficulty engineering can impact students' mental health impact and vice versa	(8)								
Take it	the pressure to endure the difficulty of engineering may be driven by the culture of academia within the United States	(4)								
	the pressure to endure the difficulty of engineering may be driven by the culture of a specific program/department/college/institution	(8)								
	there is a pressure to follow the norms and expectations of engineering	(7)								
	minoritized individuals may need to endure discriminatory behaviors if they want to stay in engineering	(5)								
	engineers use coping mechanisms to help them endure engineering	(8)								
	engineers rely on social support (e.g., peers, friends, family, religion) to help them endure engineering	(8)								
Approach problem solving using a toolkit	written text (e.g., textbooks) is a resource and part of the toolkit engineers use to solve problems	(2)								
	a students' toolkit is built through their coursework, past experiences, and advisor; assumption that graduate students have a standard toolkit/skillset using the toolkit	(3)								
	students talk about mental health with one another to expand their toolkit	(4)								
Professional development is valued conditionally	a students' path into graduate school is influenced by their social capital	(2)								
	building relationships does not directly benefit a graduate students' core work, and is therefore devalued	(2)								
	diversity, equity, and inclusion efforts are solely valued for the financial gain/opportunity	(1)								
	as faculty's primary responsibility is research, improving communication skills in courses may be valued but are not a requirement or priority	(3)								
Cooperation and competition	students can choose to work with other students to survive within engineering	(7)								
	students compete with their peers for opportunities	(3)								

Table 4-16. Participants' mental health experiences with the CEEF dimension *An Engineering Way of Doing* (continued)

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Education is used for credentials	an engineering degree/education is valued as they provide proof of a qualification that then helps students enter their desired career	(8)								
Time is a resource to be managed	given the difficulty and workload of engineering, it is assumed students will work as much as able to maximize their progress and quality of output(s)	(7)								
	time is limited, and therefore you are expected to not spend time on things that are not useful or productive	(7)								
	students must learn time management given the multiple tasks, deadlines, and time constraints they face	(8)								
	communicating quickly is viewed as being valued/prioritized	(2)								
	deadlines are typically inflexible, and on the individual to meet	(3)								
	working with others (e.g., students, advisors) can help reduce the time needed to complete your work (e.g., breakup tasks, streamline a process, etc.)	(4)								

instructor made assumptions about their knowledge base and experiences within engineering. Finally, taking a problem-solving approach to mental health concerns was generally perceived as a neutral and accepted experience

A fourth theme under this dimension is the theme *competition and cooperation are accepted within engineering*. This theme encompasses the notion that students compete for grades and opportunities, and at the same time, students share in their suffering, and can choose (or at times have no other option) than to work together to survive their program. Most participants had negative experiences with this theme as it often presented itself as a misalignment in values or that poor communication skills from the professor in a course was considered acceptable behavior. Positive experiences generally came from individuals that leveraged networks in their graduate school search process.

Nitya's experiences demonstrate these four themes. In their interview, Nitya shared:

> My first semester here, I was having a lot of trouble with one of my courses and I felt really bad because up till then, I never had any problems studying or doing well in a course … I felt really stupid and then I started missing my family, I was homesick. It's all getting bundled together and I'd feel like cutting myself off from everything … I think [engineering is] stressful at times, but also very rewarding. ... If engineering is something that you've always wanted to do at the end of your four years of undergrad, or your PhD, or I can't really speak about this but at the end of your master's you feel like you've been in school your whole life but at the same time, getting to that point can be really tough and it really depends on what kind of people you're surrounded by and that can either help make you or break you. ... One of the courses I took here at [school] in my first semester had a [lab aspect] to it and ... Basically, it was us trying to [provide] a practical

> use [for] what we were learning in class. But at the same time, I was really confused about what we were even learning … [from my experiences] if we have a class named something, I expected to learn something related only to that. But this course, I felt like it was reaching into everything that I studied in undergrad and were various courses that weren't even related and then putting that together to come up with our lab project. ... Yep. And I really, really liked how all of them [the classes] go well together and I feel like that really explains engineering really well because you don't really just stick to one domain.

Nitya shared how they had several difficulties that made engineering hard for them. In addition to navigating life in a new country, they were in a new education system, and with that, norms in how course titles correspond to the coverage of subject material in the course. This is in addition to the baseline difficulty assumed for engineering courses. At the same time, Nitya is expected to endure this. Nitya also discussed how their class lab project was a positive and rewarding experience that would provide them with training like real-world expectations for engineers. Considering the fourth theme of *cooperation to compete*, Nitya acknowledged that the individuals you surround yourself with in engineering can either help you or hurt you. Similarly, research has demonstrated the value of social supports, detailing how within higher education, social supports can empower resiliency and provide positive coping mechanisms (Amon, 2017; Sallai & Berdanier, 2022). In Nitya's experience, having social supports within her courses provided positive experiences that helped mitigate their homesickness and feelings of isolation.

Professional development being viewed as a nontechnical skill, separate from engineering concepts and curriculum is represented by the theme *professional development is conditionally valued*. That is, professional skills within engineering are usually considered "soft and easy”, and therefore only valuable within engineering professional settings when and/or where the skills are useful (Godfrey & Parker, 2010). Overall, in the study, students’ experiences are positive when the presence of these skills would aid them in completing their academic and professional milestones, and negative when these skills, and therefore potential aid, are missing. For example, as faculty’s primary responsibility is research, students encountered faculty with less-than-ideal communication or instructional skills and realized that this was considered acceptable for the university.

On the other hand, under this theme, Erik discussed a very positive professional development opportunity he engaged in that was integrated into his research. Erik shared,

> I guess it's a conference … where many of the researchers in my field [get] together [to workshop a paper you submit beforehand. This experience] was the point where I actually started to meet the people in the field and be like, ‘Oh, this is a community that resonates with me that I want to be a part of so maybe I should stay in academia.’ … [this experience is] not just like, "Okay, cool. I published a paper." … it was [also], ‘Okay, these people are pretty cool. I could get behind seeing them once a year at various conferences and stuff for the next 50 years.’

Erik shared how this professional development experience was so positive because it exposed him to others within his field that he could envision himself working with post-graduation. This experience corresponded with valuable networking and tangible deliverables for research (i.e., a paper) demonstrates how professional development can be valued within engineering (i.e., when it helps achieve other metrics of success).

Time is a resource to be managed is another theme. This theme is typically represented under the context of a learning environment that has a heavy workload and stringent time constraints and deadlines on the workload. Therefore, despite time being often constrained and limited, individuals are expected to manage this resource and meet expectations. Participants had overwhelmingly negative mental health experiences with this theme, in large part due to their workload, difficulty managing time and expectations, and uncertainty in what they were supposed to be doing. The only exception under this theme were positive experiences that came from working with others to reduce the burden and meet the deadline. Alex shared experiences with faculty in instructional environments that demonstrate a lack of value for professional skills, as well as the belief that *time is a resource to be managed*, with engineering work being the highest priority in an engineer’s life. They shared:

> I think professors and people generally are trying to make mental health resources more available for students. But my God, there's still some professors that are just really rough that should not be professors, especially in engineering. I had a classmate during my undergrad that he was just really behind on his assignments. And also his sister, he's an international student, I don't remember from where, but somewhere in the Middle East. That he was trying to go home for his sister's wedding. He hadn't been home in years. And he asked his professor if he can move up his exam to the end of classes so he could go home a week early for the wedding. And the professor was like, "No, this is when my exam is. I missed my sister's and dad's funerals for my work. It happens, we have to make sacrifices for the work we do."... One of my roommates [in undergrad] had a service dog our junior year, and some professors were very accommodating, it was very nice. But then some professors, I almost got into an argument with a professor for the audacity of asking her what illnesses she had that she should have a dog in class with her.

Alex’s experiences within a course demonstrated negative experiences with the themes *professional development is conditionally valued* and *time is a resource to be managed*.

The final theme in this dimension is that *education is used for credentials*. That is, the degree and education in engineering are valued so much as they provide proof of a qualification. Once obtained, this degree is what provides opportunities. Most students agreed with this theme. The differentiation between positive and negative experiences, however, came from whether they felt it was acceptable to share or acknowledge this belief. Zoey’s experiences touch on this. Zoey shared:

> I think I know what I want to do in the future, and I need a PhD to do that, so what's motivating me is basically the endpoint, which I realize isn't the healthiest way, always, to look at things, but that's motivating me, as well as the support that I have from my family, and my friends who believe in me, and my faith, which also give me strength to get through it … those are the things that keep me pushing forward. Not that I don't question staying with it … [I really want to teach] so I'm still thinking if I would rather do a postdoc or look for a lecturing position. I think if I could find a postdoc that was research I was more interested in and really passionate about, that would be a good opportunity to kind of learn some new skills, and hopefully have a better research experience before starting as faculty, but also, I really like teaching and lecturing, so I may also apply for jobs where I would just basically only be teaching.

Zoey shared their thought process on how the degree they were obtaining is necessary to do the jobs they want to do, such as teaching and lecturing. At the same time, it is possible that had there been more alignment in their experiences with research as a graduate student, they perhaps would have considered different roles. Regardless, Zoey acknowledges that her end goal is a large motivation for them to complete their degree. Like Zoey's experience, doctoral students often rely on external motivations in the earlier stages of their degree (Lynch et al., 2018). Furthermore, work has demonstrated students have persisted in engineering based on the high level of usefulness (i.e., utility) of the degree, even if this does not align strongly with their sense of self (Matusovich et al., 2010).

4.5.6.4 Being an Engineer

There were seven themes under the dimension *Being an Engineer*. Across these seven themes, there were 23 sub-themes (Table 4-17). The first theme was "*can-do" attitude*. Students that enter engineering are assumed to be high achievers with above average skills in math and science as well as proactive with problem solving. Consequently, peers within engineering value these characteristics and assume peers will be able to meet expectations within groupwork. Participants had negative mental health experiences with this theme as students often felt pressure to work on their own and make some level of progress before asking for help, often taking additional time and resources.

The theme *all or nothing* referred to the belief that engineers throw themselves into whatever activity they are doing, whether that be work or relaxation (i.e., work hard, play hard). Positive experiences came from either the flipside of this theme, where engineers throw themselves into their hobbies and interests, or when participants felt an alignment between their own values and these norms. However, most students had negative mental health experiences that invoked feelings of shame if not 110% committed to their research as they felt pressured to know their area of study before joining graduate school.

The third theme, pride in being an engineer, was defined by a shared sense of pride engineers feel from persisting through the difficulty of engineering and succeeding. All

Table 4-17. Participants' mental health experiences with the CEEF dimension *Being an Engineer*

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Can-do attitude	students assume that other students make a genuine effort to solve a problem before asking others for help	(4)								
Think in bullet points	mental health is communicated in a logical, bullet point manner	(3)								
	engineers communicate their work (e.g., problem solving, decision making, etc.) in a logical, step by step manner	(5)								
Stereotypes	engineers use numbers to explain technical and non-technical situations (numerate)	(1)								
	engineers are practical/pragmatic, and assumed competent with technology	(7)								
	engineers are mentally tough and self-reliant (strength of character rather than physically); they do not discuss emotions	(8)								
	engineers are non-emotionally demonstrative (trust in logic, analysis, reason)	(6)								
	engineers are conservatively mannered (e.g., dress, politics, mannerisms)	(4)								
	engineers are logical	(3)								
	engineers appreciate self-depreciative humor; this can translate to self-depreciative actions	(6)								
All or nothing	core engineering / technical work directly related to one's work is the only work considered valid in engineering, and therefore the only work valued	(4)								
	engineers throw themselves into their work	(8)								
	engineers throw themselves into their external interests (e.g., volunteering, hobbies)	(4)								
	students should know what they want to study and be committed to doing that when they start graduate school	(5)								
	assumption that graduate students would dive deeper into topics/concepts learned in undergrad	(3)								
	mental health is viewed as a dichotomy, it is either good or bad, no in-between	(2)								
Being one of the "guys"	engineering is a male dominated field	(3)								
	engineers use sports analogies when communicating	(1)								
	emotions are not talked about within engineering	(3)								
Pride in being an engineer	engineers are proud to associate themselves with other engineers (e.g., student organizations)	(6)								
	engineers value the work they do, and are proud of how they make progress and their work	(4)								
	the pride engineers feel comes from the value the work is perceived to have	(1)								
	engineers enjoy presenting their work and sharing their accomplishments	(4)								

participants had a positive mental health experience with this theme (e.g., feeling proud of being in a student organization centered on engineering, enjoyment in presenting their work and accomplishments). The negative experiences with this theme focused on the mechanisms in which progress within work was made (e.g., conditions of work environment, not accounting for ethical considerations in work), and the metrics used to determine success (e.g., profits). The fourth theme, *stereotypes*, was defined by a set of characteristics engineers are associated with (i.e., numerating, practical/pragmatic, mentally tough, non-emotionally demonstrative, conservatively mannered, logical, and self-depreciative. Most participants had negative mental health experiences with these stereotypes as they often perpetuated stigma negatively associated with individual's discussing or experiencing mental health concerns. Erik and Naomi were an exception, with at least half of their experiences being mixed (positive and negative). Erik, Naomi, Diana, and Nitya all had positive experiences when they felt an alignment between their personality traits and these stereotypes.

Naomi shared an experience they had in one of their courses that provides examples of mental health experiences with these four themes. Naomi said:

> When I first got into the [engineering program], I was super invested and gung-ho. I just wanted to do my best … so, this class that I took, we were doing these experiments [where] we didn't necessarily have to buy [materials], but I decided I wanted to be able to [really understand the assembly process], so I could [understand it] inside and out. So I took that extra step and I [assembled this item] over a weekend and locked myself in my apartment just doing this thing, so that's kind of to show, I guess, the persistence.

Naomi demonstrated their "can-do" attitude by taking the proactive step in problem solving a mechanism they would be using in a course to ensure they truly understood how it worked, echoing stereotypes of engineers (e.g., pragmatic to work on a weekend to get this level of understanding). The fact that they did this over a weekend demonstrates how engineers throw themselves into their work (all or nothing). Finally, Naomi reflected on their pride for accomplishing this task and being someone who built the mechanism. This is supported by recent research which demonstrated that the likelihood for a student to work through a problem and deepen their understanding is based on whether the student views the task as relevant (Kirn & Benson, 2018). Naomi's experience suggests that students will have positive mental health experiences if students can find relevance between their technical work and their motivations for doing the work.

The fifth theme was *engineers think in bullet points*. This theme refers to how engineers' value of logic translates into a direct, step-by-step, logical communication pattern. As with stereotypes, Diana, Erik, and Naomi all had positive experiences communicating their work in a logical, step-by-step manner. The only negative experiences under this theme came when participants felt this communication style was not the best approach to solve the problem at hand (e.g., peers unable to communicate in different ways to help overcome confusion). An example of a negative experience with the theme *think in bullet points* is demonstrated in Alex's experience working with other students earlier on in their program. Alex shared,

> I worked with a group of three or four other students in my class every week on the homework sets for my [redacted] class. And I always just felt so lost in it. I just felt my undergrad [redacted] class was not at all like it. This one's very mathematical and we used all forms of math when my undergrad felt like it just went up to algebra two. And I just did not feel prepared for it and I felt super behind. ... And there was a lot of skills I learned as an underclassman in undergrad that I feel like I didn't use. But essentially, one

of the days that we're working [until] 7pm at night, and I just didn't. Everyone's talking, everyone in my study group's talking like they know exactly what they're doing. They're like, "Okay, that makes sense." And they're like, "You just do that." They're trying to work together, and I felt like I was dissociating almost because I just felt super overwhelmed. I was just staring at my paper, staring at my computer with [software] open. I just felt I had no idea how to do it. And my voice started cracking and I turned to my friend that was in my group with me and I was just like, "How do you know all this? I don't understand." ... And I just guess looked so panicked and so overwhelmed and [there were] just like, "Well, you just do it. It's just from this." And I'm just like, "What do you mean by that?" And I just started bawling my eyes out in the middle of the [location] … I just felt so overwhelmed. And I remember just, I think I said something along the lines of, "Well, I'm the dumbest one of this group. I guess I just don't get it," and then I ran off into the bathroom and cried for a solid 15 minutes. And I remember coming back and they all just looked very awkward, and they didn't know how to help.

Alex shared their experience working with peers in engineering on a homework assignment. Alex shared how they felt there was a barrier to being able to communicate with peers. Specifically, Alex’s friend tried to help Alex understand how to complete the homework assignment by iterating where they were within the logical step-by-step process of getting to the answer (e.g., thinking about the process as steps broken down into bullet points). However, Alex was not able to follow this process, resulting in them feeling overwhelmed and underprepared from their undergraduate experiences. Feeling insignificant within STEM settings can predict increased levels of distress whereas being able to perceive success to be relative to one’s peers predict increased levels of well-being (Fisher et al., 2019). In Alex’s case, their distress came from feeling lesser than their peers, which Alex suggested might have come from their previous education not preparing them as well as their peers.

The last theme under the *Being an Engineer* dimension was *being one of the "guys,"* which was defined as engineering being a male-dominated field, and with that comes expected behaviors (e.g., profane language, semi-sexual innuendos, sport metaphors, etc.). Most negative experiences related to the assumptions of being one of the "guys" comes with the understanding that emotions are rarely expressed or discussed, such as with Alex's experiences after returning from the bathroom. Research supports these experiences, documenting how emotions are not acceptable as this is considered a feminine trait, and therefore undesirable within engineering (Bastalich et al., 2007; Tonso, 2001).

In this study, an exception to this norm was that displaying emotions related to sports was considered acceptable. In these cases, participants had positive mental health experiences. In a direct example, Erik commented on their love for basketball:

> [T]his is one of those things where I'll be sitting, watching basketball in my room and my housemates will hear me downstairs go like, "Woo. Woo. Let's go." And they're like, "Oh, Erik's just watching basketball again." But yeah, it's one of those things that a lot of the times I find myself getting kind of excited. Teaching or something, I have a pretty even demeanor. So yeah, my housemates are like, "This is the only time we've ever seen you demonstrate any sort of strong emotion whatsoever is when you're watching basketball. Particularly when [team] is either doing really well or doing very poorly.

Erik shared that although they are typically mimicking stereotypes of engineers by being non-emotionally demonstrative inside and outside of engineering, that they find themselves having positive mental health experiences by being able to fully engage and express themselves with basketball. More indirectly, Aiden shared their experience working with others to solve homework problems:

> Some happy moments [from my time as a graduate student] include finishing big projects or hard homework problems in the work room [myself and others in my cohort would] frequent. [Completing a class] report was one [example] where we'd gather around whoever just submitted it to cheer them on. Many of the highlights of my PhD experience so far have been with the cohort.

Here, Aiden shared their experience working with peers in their departmental cohort. Although emotions are not usually considered acceptable for engineers to share, in this experience Aiden details how it is acceptable for peers to cheer one another on after completing a major assignment, much like Erik cheers on his favorite basketball team when they are doing well.

4.5.6.5 Acceptance of Difference

There were four themes under the dimension *Acceptance of Difference*. Across these four themes, there were 18 sub-themes (Table 4-18). The first theme, *homogeneity*, was defined by the high levels of shared attitudes, beliefs, norms, and values engineers hold and/or expected to conform to. This was also based on the assumption that engineering students have similar backgrounds and experiences (e.g., education). Almost every mental health experience with this theme was negative. Students felt a misalignment with engineering cultural norms (e.g., belief in meritocracy, individualism, etc.). Furthermore, most minoritized students in this study (whether by race, gender, or both) had both witnessed and experienced acts of discrimination as a graduate student. The only positive mental health experiences were from individuals who did not experience or witness discriminatory behaviors and felt they belonged within engineering – Aiden, Erik, and Nitya. That is, the two White male doctoral students and the only international

Table 4-18. Participants' mental health experiences with the CEEF dimension *Acceptance of Difference*

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Homogeneity	the assumption that engineering graduate students have similar backgrounds, experiences, and expectations on graduate school	(5)								
	high degree of homogeneity within the attitudes, beliefs, norms, and values engineers are expected to hold and/or conform to	(7)								
	individuals may experience discriminatory behaviors if they fall outside the expectations of what/who an engineer is	(8)								
	engineers believe that personal and career successes are primarily the result of an individual's hard work within a fair system (meritocracy and individualism)	(8)								
	engineers believe that their work is objective and unrelated to social or political concerns (depoliticized)	(6)								
	engineers believe that "technical" engineering competencies are separate from, and more important than, "social" competencies (social-technical dualism)	(6)								
	engineering work is motivated to maximize profit (capitalistic)	(3)								
Conditional acceptance	ways students are assessed for inclusion within engineering (e.g., background, abilities, characteristics, etc.)	(8)								
	experiences considering or trying to assimilate to the dominant engineering culture and/or downplay aspects that make them an outsider	(6)								
	conditional acceptance applies in social contexts (e.g., student organizations)	(7)								
First impressions	first impressions may impact the graduate student – advisor relationship	(7)								
	first impressions may impact a graduate student's interactions within their program, department, institution, and/or the discipline	(3)								
	first impressions in a student's degree may align with their assumptions on graduate school	(8)								
	first impressions and shared backgrounds and experiences may help form friendships	(7)								
Prove yourself	engineers should always be working to prove their commitment to engineering	(8)								
	engineers can leverage social capital to elevate someone's acceptance within the field	(6)								
	engineers can gain credibility by passing milestones and/or successful defending their work	(5)								
	individuals not initially accepted into engineering can gain credibility by persisting (and succeeding) within engineering over an extended period of time	(4)								

and master's student. This is not to say that they did not also have negative mental health experiences; rather that their negative experiences were not the result of overt or covert discrimination or feeling that they did not belong within engineering.

This theme relates closely to the second theme under the dimension Acceptance of Difference: conditional acceptance. Conditional acceptance refers to the fact that individuals within engineering are always being assessed for inclusion within engineering. As a result, many individuals feel that their acceptance into engineering is based on their ability to assimilate and/or hide/downplay what makes them different as well as conform to aspects under the dimension Being an Engineer. The positive mental health experiences under this theme came from a social support (e.g., friend, peer in program, advisor, etc.) that acted on the participants' behalf or interacted with the participant that gave them some sense of belonging within engineering. However, as with the theme of homogeneity, most mental health experiences were negative. All students communicated frustration in the ways they felt they were being assessed for inclusion within engineering, and many had negative mental health experiences trying to conform to these norms (e.g., Diana's experience trying to collect data with their advisor).

The third theme, *prove yourself*, referred to the chance that individuals may be able to change how others within engineering perceived and/or accepted them if they could adequately prove themselves. Proving themselves generally referred to demonstrating their technical abilities, and usually included overcoming prejudices and biases. That is, the burden of proof that an individual belongs within engineering was placed on the othered individual (i.e., assumed incompetent until proven self to be competent). The positive experiences under this theme were from individuals reflecting on when they passed milestones and successfully proved themselves or from individuals having social supports advocate on their behalf that they belonged. However, as with the previous two themes, most participants had negative mental health experiences that came from experiencing discriminatory behaviors within engineering.

The fourth theme, *first impressions,* was based on individuals within engineering forming initial relationships based on what they perceive other's engineering abilities to be, how successful they think this persona will be within engineering, and if they perceive this relationship to support their own personal success within engineering. Initial relationships within engineering are therefore typically formed based on shared interests, backgrounds, and experiences as these can be leveraged as social capital to build trust. Most students had positive experiences forming relationships and connections based on shared backgrounds and experiences. However, every minoritized doctoral student felt that building relationships within engineering was a slow and/or painful process. This process made students hyperaware of atypical aspects in their background and/or experiences and made them feel othered. Adrian discussed experiences they had within engineering that touches on all four themes under this dimension. Adrian shared:

> I would put up messages and quotes and stuff from generally radical or little points of view on a white board at my desk. The White dude that is [a staff person] for [my office] one day just comes clears it all out. I'm like, "Hey, what the fuck? Why did you clear this out, and not the other people's shit?" He was just like, "I'm not fucking doing this with you. Just don't put it back up." No explanation. Don't put it back up. I'm like, "Why? What are you trying to target? What is this?" I felt targeted. But yeah. It's things like that. Right? It's generally not a lot of overt discrimination. ... It's generally not a bunch of overt discrimination in public spaces, but a lot of the microaggression[s]. I remember I was at an event with one of the professors in [their department] that's generally come to be

> known as pretty problematic, but [their department] doesn't give a fuck about that. There's no sense of them trying to do anything in relationship to accountability. The dude was pretty much like, 'yeah, I remember we spent a lot of time looking over your application for admissions because it took a long time.' To me, that was a hint. "Honestly, I don't think you should fucking be here." Just given the way he phrased it. It's like, okay. I mean, what am I supposed to take away from that? You're a professor in [my department]. Why are you hinting at the fact that I should not be in [this department]? What is that? What is that supposed to do for my mental health?

Adrian's two experiences detailed how their interactions with staff and faculty made it clear to Adrian that they did not belong. The first experience discussed how a facility manager removed materials from Adrian's workspace because they communicated viewpoints the manager disagreed with, and when confronted by their actions, was directly told not to put things like that up again. This experience demonstrated the themes of *homogeneity* and *conditional acceptances*, whereas Adrian was singled out and retaliated against for having communicated something against the norms of engineering. Their second experience highlighted negative mental health experiences with all four themes. In a public setting, a faculty member in Adrian's department communicated that it took a long time reviewing their admission into their doctoral program, with the subtext that the faculty believed Adrian should not have been admitted. Not only did that make Adrian feel othered and not accepted, but it made it clear that with this faculty, and perhaps with others in their department, Adrian needs to prove that they belong. When reflecting on these types of experiences, as put by Adrian, "*It's generally not a bunch of overt discrimination in public spaces, but a lot of the microaggression[s]*."

Erik's positive experiences within this dimension were the main outlier. Erik's positive experiences came from their transition into graduate school. Erik shared:

> I did my undergrad at [an ivy league institution and decided to put off] getting a job until [after] graduate school. So literally the only thing that I knew about graduate school was I need to go do this thing later to become like a quote-unquote "real engineer" and get an engineering job if that's actually what I want to do. So at no point was it ever actually my intention to do a PhD until I started applying to [program]. It was just like, [lets apply to top tier programs and see what happens]. And pretty fortuitous coincidence, [institution] came back and was like, "Hey." The [graduate chair] was like, "Hey, we think you'd be a good fit for the PhD. We have this new faculty member, [advisor] that we just hired, that..." The subtext was they're having some trouble finding [students] and I seemed like a great fit. So they're like, "Hey, do you wish to do a PhD instead?" And I was like, "Okay. Yeah, I guess so." … And my impression is that this was very unusual for the [graduate chair] to do. It was, I think, the grad chair acting more or less unilaterally … [I was also] invited me to [come to a campus visit for prospective students]. So I came and talked to a few people, including the [graduate chair], and I was like, "Okay, so how would this actually work, right? You've admitted me to the master's program. Can I just start the PhD?" And they're like, "Well, no, not really. You could come here and then be here for a semester and then transfer in" [but as I was planning to take a gap year for a study abroad opportunity after discussing deferment options] they basically were like, "Oh, well you can't technically defer, but we'll just roll over all of your application materials and give you a fee waiver." And then also, I hadn't done any research when I originally applied to the master's program because I was applying October of my senior

> year, but I did a year of research during the senior year … and they're like, "We'd like to see a letter of recommendation from your research advisor because that was the one thing that your portfolio was missing that would show that you can do a PhD."

Erik discusses their unintentional path into a doctoral program. Initially having applied to a master's engineering degree program, Erik was approached by an individual in a position similar to a graduate chair level and encouraged to do a doctoral program instead. Erik went on to share how they chose to do a gap year, and in that time these individuals allowed Erik to carry their application over to the following year (at no additional cost). Furthermore, they coached Erik on aspects missing from their application and allowed them to submit additional materials to fill out this missing piece. When asked to reflect on this experience, Erik shared:

> Something that I very quickly realized within my first year or two here, is that I basically ended up [here] completely by accident. But I very quickly realized this is what I'm meant to be doing. I could not have picked a better next career move if I tried, and I ended up here completely randomly. As an advisor, [they were] a perfect fit for me. Especially the stuff that I was doing at the very beginning was like, 'This is the research that I want to be doing. This is the field I want to be working in. These are all things that are really interesting and give me meaning.' … So it ended up being something where it's like, 'I'm very glad that this is how things just happened and worked out because I didn't choose it intentionally.'

For Erik, although not intentional, their experience with engineering was ideal given the trust and belief someone in a position of power had and enacted with them. Although Erik still found aspects of their degree to be difficult, Erik never doubted whether he belonged within engineering. Comparing Erik and Adrian's experiences demonstrates how norms within engineering, although communicated to be based on beliefs of meritocracy and depoliticization (Cech, 2014) are enacted by human beings. Individuals can consciously, and unconsciously, have their own biases and prejudices, which in turn can shape both the culture of engineering as well as how this culture is enacted.

4.5.6.6 Relationships

There were three themes under the dimension *Relationships*. Across these three themes, there were eight sub-themes (Table 4-19). The first theme, *collaborative*, referenced engineering being a largely collaborative space. A students' workload, time constraints, and the difficulty of engineering facilitates common shared experiences among students (e.g., struggling through engineering) that incentivizes students to collaborate. All students had positive perceptions related to this theme, with all students enjoying and valuing collaboration. Furthermore, most participants had positive experiences collaborating within their courses and research settings. Although some students did have experiences where collaborations did not go as they had hoped, most negative mental health experiences occurred due to students being unable to collaborate with others as much as they wanted to because of the switch to virtual learning during the coronavirus pandemic.

For example, Nitya shared their positive experiences entering the equivalent of a campus union: "*The first time I walked into [the campus union] is a sight I won't forget. I was excited about studying here and looking forward to all the connections I could make*." Nitya shares how they were excited about the possible connections they could make at the start of their program. Some of these experiences were realized for Nitya. When reflecting on their courses, they shared the following: "*I really like the courses that they were offered for my specialization … [faculty and staff] were quick in responding, and also came to be really present to help me out with*

Table 4-19. Participants' mental health experiences with the CEEF dimension *Relationships*

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Collaborative	assumption that engineering is collaborative and values collaboration	(8)								
	collaboration is motivated by a shared mentality of difficulty (i.e., shared struggle mentality)	(5)								
	collaboration is facilitated by in-person interactions	(4)								
Mates	it behooves students to form friendships with peers in engineering to support one another through the degree and milestones	(6)								
	friendships can extend outside of the classroom (e.g., student organizations)	(3)								
Student - faculty interactions	student-faulty interactions in engineering are influenced by the culture of a student's specific program/department/college/institution	(3)								
	student-advisor relationships are overall positive and allow for more informal interactions	(8)								
	student-non-advisor (i.e., other faculty or possibly staff) relationships are overall positive and allow for more informal interactions (e.g., professors in courses)	(6)								

anything that I [needed help with during the course]." Nitya shared a positive mental health experience of being able to work with staff and faculty within courses in their specialization and feeling supported. However, later in the interview when Nitya is asked to reflect on their experiences, they shared how the pandemic impacted these experiences:

> I guess the Covid-19 situation [was] pretty bad … I feel like I missed out on the university experience because all my classes were virtual. I missed going to classes and being able to take advantage of all the resources that the university had to offer … maybe being able to attend classes in person, or being able to go visit a different place without worrying, or in general meeting my friends.

Nitya shared how the pandemic really altered their graduate school experiences because of the transition to a virtual environment. Not only did Nitya not have access to resources on campus, but the pandemic also made it so that they were unable to meet with individuals, limiting their ability to make the connections they were so excited to make. This in turn may have contributed to Nitya feeling isolated and sad, as well as their self-reported scores aligning with the diagnostic category of moderate depression. Likewise, their experience reflects recent studies that found that students' mental health got worse because of the pandemic (Young Minds, 2020).

Mates, the second theme of this dimension, referred to the incentive for students in engineering to form friendships with others in engineering. The theme mates merges concepts from other themes (e.g., first impressions, time). That is, acknowledging that it behooves students to form relationships with their peers to help them succeed in engineering, and recognizing that students will be spending a lot of time doing engineering work, it makes sense for students to form deeper levels of relationships (i.e., friendships). This theme had most positive mental health experiences, with participants finding themselves able to form friendships with their peers within their courses and extracurriculars. For example, Naomi shared the following: "*[I feel a sense of belonging with] students who were enrolled in the same class that I took last semester and now are also taking the same/similar classes this semester. We have frequent study sessions and message each other often*." Naomi shared how they formed friendships with peers who take the same courses they do, often studying and communicating with each other.

The third theme referenced the interactions between students and faculty (dubbed *student – faculty interactions*). Overall, students are aware of power and generational differences that exist between themselves and the faculty and staff at an institution. However, within engineering, as students interact more frequently with faculty, trust and rapport can build. This can allow interactions to become more informal and friendlier. Experiences with this theme varied based on how participants viewed their relationships with their advisors or non-advisor faculty and staff. Most students had positive mental health experiences with their faculty advisors where they felt that the faculty supported them and wanted them to succeed. However, negative mental health experiences were prevalent when students did not feel like faculty were supporting them in their studies. Zoey shared their experience with their advisor:

> [I think my] advisor-advisee relationship has an enormous impact on my mental health ... I like my advisor as a person, very much, and respect them a lot, but I think often, it is frustrating, because it feels like they don't really prioritize helping me. Like, as far as helping me set goals, or helping me plan my study, or giving me the resources and support that I need, I often feel [unsupported and] that we don't have great communication, just because our personal communication styles are different. So, that oftentimes, I leave our [weekly] meeting feeling incredibly frustrated, or I often feel

> discouraged, because I feel like I have to figure something out on my own, and I can't get help with it. For that reason, I feel like if I had a more intentional advisor, that might be helpful. And this is just speculation, but I think also because my advisor has tenure, and might be close to retiring, they're kind of at the point where they don't really care as much as some of the younger professors that are still trying to establish themselves and still highly involved in the research. [Trying to] figure out effective ways to communicate has taken up a lot of mental energy .... It isn't the frequency of communication that's a problem. We meet every week, and that is plenty. It's more of the amount of time that I feel that my advisor spends thinking about my research outside of our meetings. I basically feel that they only really think about my research during those [half hour] meetings every week, as opposed to me thinking about it all the time … I feel that I come extremely prepared for the meetings, and that my advisor would be distracted, or unprepared, or uninterested in the meeting.

Zoey discussed experiences they have had with regards to their relationship with their advisor. Although Zoey respects and likes their advisor, they feel unsupported by them. This is communicated through weekly meetings in which Zoey feels their advisor is unprepared or even disinterested in the meetings. This in turn caused Zoey to feel unsupported by their advisor and frustrated by the additional burden of troubleshooting communication approaches to try and find an effective way to get the help they needed. Zoey shared how this took a large emotional toll on them, and negatively impacted their mental health. As detailed in research, advisors can support positive mental health experiences by validating a student’s concerns, confirming that they belong, or providing opportunities (Amon, 2017; Posselt, 2018). It stands to reason that by not providing these supports, advisors may be promoting negative mental health experiences.

Furthermore, it is largely acknowledged that the student-advisor relationship is central to a student's success within their degree program, with concerns Zoey shared being cited among reasons for dissatisfaction with one's advisor (e.g., misalignment research interests, communication norms, advising style, expectations on support; Bork & Mondisa, 2022)

4.5.6.7 Relationship to Environment

There were three themes under the dimension *Relationship to Environment*. Across these three themes, there were eight sub-themes (Table 4-20). When discussing the findings, it is important to note that Erik's recruitment process into their doctoral degree was a positive experience not shared by other participants that is represented under the three themes in this dimension. The first theme, *situated within several ecosystems*, referenced that an individual's experiences within engineering educational environments is shaped by several environments embedded in one another. This includes the environment at their academic institution, the degree of oversight and/or involvement of the engineering profession, and the cultural landscape of the geographical location (including political, economic, and social contexts) they are situated within. Nitya's positive experience came from the influence of the engineering profession on their degree program, specifically in the alignment between their courses and the preparation this provided for their desired career path. Other students' negative mental health experiences were connected objections with cultural norms that impacted their engineering work (e.g., social-technical dualism, capitalism). For example, Adrian shared:

> [My department was in a] Town Hall, most of what [my department chair] talked about was how much money our department brings in relationship to the entire college and the entire university. We looked at DEI as money. ... I feel that at some level of engineering

Table 4-20. Participants' mental health experiences with the CEEF dimension *Relationship to Environment*

Theme	Sub-Theme (number of participants)		Adrian	Aiden	Alex	Diana	Erik	Naomi	Nitya	Zoey
Situated within several ecosystems	experiences within engineering can be impacted by the academic environment of the institution	(8)								
	experiences within engineering can be impacted by norms within the engineering profession	(6)								
	experiences within engineering can be impacted by the cultural landscape of the nation (including political, economic, and social contexts)	(7)								
Desire for autonomy and independence	engineering establishes policies that favor those within higher positions of power and value to engineering	(6)								
	engineering can enforce their values and norms onto students with minimal oversight	(8)								
	engineering strives for independence and autonomy from other disciplines and/or fields, within and outside of higher education	(5)								
Inherent oversight	engineering is overseen by a university, and therefore still held to governmental (local, state, national) and funding agency regulations	(5)								
	engineering is situated within the United States, and therefore is held to national policies and regulations	(6)								

> culture, right? It feels so profit driven, which I guess relates to [the movie poster] … he puts the glasses on, and he sees through all of the ideology. Oh, this is good, right? We're doing things that are positive. And it's just, okay. It brings us wealth.

In this experience, Adrian shared how leaders in their program discuss work being valuable if it contributes to the overall equation for profit gain. For Adrian, this was a very negative experience because it centered the work under a capitalistic lens rather than its intention to create diverse, inclusive, and equitable learning spaces.

The second theme, *desire for autonomy and separation*, was defined as how the discipline of engineering strives for autonomy, independence, and minimal oversight wherever able. That is, although engineering is situated within several systems, engineering, and those within engineering, desires to act separately from those systems with its own set of norms, procedures, and policies. All students had negative experiences with this theme as they found engineering's desire for autonomy often resulted in policies and practices that were not favorable toward students. Diana's experiences trying to get support in navigating their advising relationship provides an example experience of this theme. Diana shared:

> I felt like I had a hard time getting the change that I wanted to see [with my advising relationship]. I wish there was almost someone that could say, "No, this is not right. We need to see changes." And I feel like people kind of were a little hesitant to do that. ... I think it was specific to my advisor, but then a challenge was like okay. I did complain, so when I complained, I didn't feel very protected as a student. So then I think that's the systemic part. How do we protect students? I requested that the things I share during those meetings not be brought up to anyone else, but I got the strong sense that it was just because of how things happened. And that made me feel like I don't have a safe space to

> share what I need to. And the action items after I did bring these things up with the department was, "Okay, share with me how things change over time. Let me know," versus let me talk to this person ... I felt like people were very afraid to kind of step on toes, which makes sense. But there's also, what I realized toward the end is the [faculty in engineering I talked with] is a mentee of my advisor. So I guess it makes sense. [They didn't] want to step on [my advisor's] toes either. But I think that kind of just brings to light some of the challenges like if there are conflicts of interest. And I think there just needs to be people that, with people that aren't within the [department] and then also have a strong say in what they can [do] ... maybe consequences or something that they can do to actually enforce change.

Diana shared how difficult it was for them to get support in their advising relationship. As engineering has its own policies for navigating difficulties within a doctoral student advising relationship, Diana had to work within this system to get support. Diana shared how this process was frustrating, and how they felt there was a conflict of interest in the process. That is, Diana went to another faculty member for support, but they would not help Diana because they did not want to upset their colleague, Diana's advisor. She ends by commenting on how it would be beneficial to have others engaged in this process who were not situated within their specific engineering department. Their experience demonstrates how within higher education (e.g., an engineering department), when things are handled internally (i.e., without external oversight), there is a risk of introducing biases and/or power dynamics that can impact the outcome of these processes.

Oversight was the third theme under the dimension *Relationship to Environment*. This theme recognized that although engineering as a field (as well as a program within an institution) desires to be self-sufficient with minimal oversight, it is still overseen by and held to regulations within the academic institution, respective government (local, state, national), and funding sources. Students mostly had negative experiences because of the switch to a virtual learning environment during the pandemic, which was enforced by governmental and university policies. However, for some minoritized students, the move to a virtual learning environment was a positive experience as it allowed students to distance themselves from spaces that were psychologically harmful to them. As shared by Adrian:

> Honestly, the pandemic has been helpful [because] I don't see any of these fucking people … Literally having the social distancing away from these people has helped tremendously. I don't have to deal with it. Right? I can literally just check the fuck out. I'm not forced to remain in this space.

Adrian shared how the move to a virtual environment and social distancing, enforced because of the government regulations and enforced lock down/quarantine, led to positive mental health experiences as they no longer had to put themselves into a space or interact with individuals that negatively impacted their mental health. That is, whereas normally Adrian's educational experiences would have required them to be in person within spaces that harmed them, these expectations were overruled by government regulations. Although an extreme case, this demonstrates ways external regulations could be used to change the culture and experiences for students within higher education. As minoritized students are known to use self-preservation coping strategies to persist within toxic work environments (Bork & Mondisa, 2022; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010), these findings suggest that further oversight from agencies outside of engineering could be leveraged to support students.

4.6 Limitations

As the goal of this work was to understand the range of emotional experiences engineering graduate students' experience and how the culture of engineering plays into these experiences, there are limitations on the conclusions that can be drawn from these findings. First, the intent of this work is not to be generalizable, but rather, to provide a rich narrative of the mental health experiences for engineering graduate students at an HWI. In particular, the goal of qualitative research is not to provide generalizable results, but rather to provide rich context for findings to translate to other settings (Borrego et al., 2009; Merriam, 2009). The results section provides some of the context we thought would be relevant to help in the translation of findings to other settings; however, this information is not exhaustive and may not include information needed to translate findings (e.g., sexual orientation, post-graduate career intentions, etc.). Although there were seven engineering disciplines represented, transferability of these findings may be limited to individuals at similar institution types. Furthermore, participants in this study were mostly doctoral students, with only one master's student who was also the only international student represented in this study. These demographics affect the transferability of findings as well as findings with respect to these students' experiences.

Furthermore, the images and captions collected from participants were to reflect on their experiences thus far, and as mentioned by participants, the events and stressors going on in participants' lives impact their responses. It is unlikely that all aspects relevant to these experiences or all relevant experiences were captured in this study, and therefore this should not be seen as an exhaustive list of mental health experiences or relevant factors for engineering graduate students' mental health (e.g., missing any discussion on financial concerns).

As discussed in the positionality statement, the first author led the study, from conception to data collection to analysis. Although they accounted for their positionality and used several triangulation methods, they are limited in their ability to fully understand and validate the lived experiences of many of the participants. The second author's expertise and own lived experiences helped to challenge the interpretation of the findings. At the same time, there is an inherent risk that the narratives presented may not include aspects the participants desired to share.

Regarding findings on the culture of engineering, the analysis conducted was guided by a theoretical framework (CEEF); however, this framework was developed using data collected on undergraduate engineering students in New Zealand in 1998 (Godfrey & Parker, 2010). Therefore, it is likely that this framework omits factors that may be relevant to graduate students within the U.S. over twenty years later. Applying the analytical framework (EST) helped attune to some of these potential factors (e.g., the coronavirus pandemic). Nevertheless, there are likely aspects of the culture of engineering relevant to graduate students that were missed as a result. For example, students at the intersection of multiple marginalized identities have unique experiences that differ from other marginalized identities, and as the framework stands, they are currently grouped together as "others." Although this does speak to the culture of engineering, future work should consider revising the framework to account for the range of unique experiences.

Finally, this study analyzed data from three different sources collected over a three-month period. Although there were some items discussed in multiple formats, future longitudinal research could provide a better sense of students' mental health experiences over their graduate school career as well as attune to shared degree milestones or experiences to aid the cross-case comparative analysis.

4.7 Future Work

The overall recommendation is for future researchers to expand on this work, replicating photovoice studies at other universities and institutions of higher education. Experiences at one HWI cannot translate to all institutions that serve graduate students. However, there are several other implications for future research that comes from this work. I present these recommendations using the six levels of EST. This will help to situate recommendations and future work by the different systems that makeup an engineering graduate students' mental health experiences as well as organize the many possible research directions that can come from these findings. In the following sections, I first provide a refresher of the system level before reviewing the findings relevant to that level. I then discuss implications and recommendations for future work within that level, repeating this process for all six EST levels. The recommendations shared seek to promote positive mental health experiences for engineering graduate students and to help mitigate or reduce the impact of negative experiences.

4.7.1 Individual (backgrounds, experiences, and identities)

The EST individual level refers to demographics and identities that are central to a person. Therefore, relevant experiences from participants were based on their demographics and identities. Future research should explore the nuances found in mixed mental health experiences across both shared and differing backgrounds and demographics of engineering graduate students. It was clear from this work that some experiences were shared and uniform across students within the study, yet some were unique to specific backgrounds, experiences, and identities. However, we do not fully understand these nuances.

Findings with regards to the culture of engineering detailed how there was an assumption that all students have shared backgrounds, experiences, and identities as well as an alignment of values with the norms of engineering. Most students had negative mental health experiences as this assumption was not true for them. For example, there was a gender difference in self-reported depression scores. All participants whose gender identity was female had scores aligning with the category of mild or moderate depression, whereas those who identified as a male or nonbinary had scores aligning with the category of minimal depression. Interventions should be developed to target the diverse population of engineering graduate students and their range of mental health experiences. For example, individuals considering graduate school may benefit by reflecting on their motivations for pursuing a graduate degree, as well as if or how their backgrounds are influencing this decision. This can include discerning from their own intrinsic motivation from that of external forces that may be impacting their decisions. Furthermore, it may help individuals to see how their experiences and personal values align with aspects they consider to be important for an engineer to have and could help build their identities as engineers (Carlone & Johnson, 2007). Finally, it may be beneficial for students and institutions to share information on student populations' past demographics to help students see what types of students go to these schools (e.g., hobbies, future career intentions, etc.). For example, providing student spotlight profiles or creating a newsletter for prospective students.

Future work should examine students' motivations for pursuing graduate degrees and how these may differ based on students' experiences and/or backgrounds. For example, researchers have explored motivational differences between students who went directly to doctoral programs and those who practiced engineering before returning to graduate school; they found that returning students' motivations had higher levels for the costs of pursuing a PhD (Mosyjowski et al., 2017). Future work can expand on this work to look at not only pathways into graduate programs, but also how students within similar pathways may have diverging motivations. For example, expanding on work that has demonstrated that minoritized students within STEM are motivated by altruistic goals (Brawner et al., 2015; Carlone & Johnson, 2007; McCormick et al., 2015; McGee et al., 2016; Seymour & Hewitt, 1997; J. L. Smith et al., 2014; Thoman et al., 2015). This work would provide insight into the different goals students have for pursuing a graduate degree that in turn could be used to reform how graduate instruction is conducted. For example, adjusting curricula to shift some emphasis to altruistic efforts within engineering may better align with the interests of minoritized students. As a result, this may help increase minoritized students' sense of belonging and improve their retention within their degree program.

Future work can explore how students' motivations for a graduate degree change throughout their degree program. For example, it has been found that international students undergo psychological distress during the transition to graduate school in the U.S. from a variety of factors (e.g., adjusting to a new educational system, feeling homesick or loneliness, experiencing discrimination and stereotyping, etc.; Rice et al., 2012). The prominence of these stressors can change over time as students' progress through their degree program, which can in turn impact their salient motivations. By being able to understand when, where, and why students' motivations for completing their graduate degree change, instructors, faculty, staff, and engineering programs can work to build in supports that speak to these motivations. This in turn may help students perceive continued value in their degree programs, and therefore may increase their intentions to persist and degree attainment.

Finally, researchers can explore interventions within the graduate school recruitment and transition processes that could provide students space to critically reflect on their motivations for pursuing a graduate degree. These reflections may allow students to become aware of their goals, and therefore better align their values, intentions, and behaviors to achieve these goals.

4.7.2 Microsystem (direct environment)

The microsystem level focuses on an individual's direct environment, including the different activities they participate in as well as the roles they serve and interpersonal relationships they form in these activities. Under this level, students discussed feeling overwhelmed in navigating their roles as graduate students. I recommend future work explore interventions that acknowledge the different roles and responsibilities graduate students may have, and how these roles may compliment or compete with one another. These comparisons can help define the different asks and expectations for graduate students which can then be mapped to different roles (and sub-roles) graduate students may have. This in turn can be used to identify assumptions made on the competencies graduate students have entering these roles and potential alignment for when one role may better serve a student during their degree timeline than others. Furthermore, there is an opportunity to identify professional development opportunities to support students in various roles through resources, mentors, and even examples of how other students have approached these roles. For example, recent graduate students wrote a book on practical teaching pedagogies for fellow graduate students to help provide advice and resources they have used in graduate instructor roles (Armstrong et al., 2021). Leveraging resources like these in professional development for graduate students can provide structure and reduce uncertainty for how students can be successful in these roles. This in turn may create positive connections between the different roles graduate students face, which can increase a students' positive mental health experiences as well as potentially build in resilience towards future negative mental health experiences.

Many students discussed experiencing feeling othered and discriminated against for not conforming to the assumed norms and values within engineering. Engineering continues to be dominated by White males (American Society for Engineering Education, 2021; National Academy of Engineering, 2004), and as a result instilled cultural norms, values, and practices that were created by this population continue to be perpetuated. Eurocentric values have been demonstrated to be perpetuated within engineering teams (Henderson, 2021). Henderson found that regardless of the number of ideas minoritized students contributed, minoritized students' ideas were less likely to be enacted (2021). On possible intervention could be regular bias assessment and training for individuals within higher education. That is, having individuals assess the assumptions they make that can perpetuate harm to bring awareness to how they may be doing so within engineering. Furthermore, work can be done to create structures and assessments of success that remove or mitigate discriminatory biases. For example, work centered around the graduate records examination has demonstrated the problematic nature of this assessment, and institutions of higher education have begun shifting away from using these assessments for graduate school admissions (Clayton, 2016; C. W. Miller et al., 2019; C. W. Miller & Stassun, 2014; Young & Caballero, 2021). Future research can expand examination of practices like these into other assessments within graduate programs.

4.7.3 Mesosystem (cross over between direct environments)

Transitioning to the mesosystem level, I now switch the focus to connections between two or more microsystems (e.g., shared content between a students' role as a researcher and a graduate student instructor). I recommend that supports be built to recognize the connections between various students' activities, roles, and relationships. For example, within courses, instructors can emphasize connections between subject matter and potential extracurricular activities, industries, and/or hobbies. Given students' positive experiences visually communicating knowledge, providing visual aids could further support students. One example could be a Venn Diagram detailing how a specific skillset (e.g., using a signal generator) could be leveraged in future courses or career paths. In addition, graduate students' motivations to obtain a degree usually include post-graduation career opportunities. As less than one-fifth of graduate students go into tenure track research positions (Larson et al., 2014), I recommend future work explore connections between the work graduate students do and these possible employment avenues. This can also help build in supports, within and outside of formalized curriculum, that can help students prepare for and enter their desired careers.

Students discussed the value they had in finding communities and networks within graduate school, and how these support systems helped them navigate negative mental health experiences. However, students also shared how relationships within engineering are usually formed based on first impressions, which can introduce biases and discriminatory behaviors against those with different backgrounds, experiences, identities, and values. In this aim, I recommend future work explore ways to foster connections between students to move past initial impressions and facilitates dialogue that emphasizes commonalities between students. For example, researchers have developed a dissertation writing intervention for students in the final stages of their doctoral degrees (Carter-Veale et al., 2016). Researchers recognized that challenges minoritized students confront completing their dissertations (and graduating) extend past program and disciplinary boundaries, including feelings of isolation, writing paralysis, and a lack of direction and measures of progress. The intervention implemented provided multiple, interdisciplinary mentors and a cohort-based model that significantly increased their likelihood of completing the dissertation and graduating that is attributed to both the structure and interpersonal support participants experienced (Carter-Veale et al., 2016). Future researchers can continue to explore interventions like these to build community and support for graduate students within and outside of academic settings (e.g., roommates, mentorship programs, athletic teams, etc.).

4.7.4 Exosystem (indirect environments)

The exosystem pertains to settings and experiences outside of a graduate student's direct environment (i.e., their indirect environment). These indirect environments affected participants' mental health experiences. A major component of this is the faculty-student relationship, whether that be within courses, research, or program settings. Many of students' negative mental health experiences came from experiencing discrimination and confronting biases (overt and covert) during their studies, as evidenced by other work literature (Bork & Mondisa, 2022; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). In alignment with assessment and training on personal biases, I recommend there be formalized policies and procedures for students (and faculty) to bring forth grievances when harm is done. The goal for these policies should focus on the students' needs and success. This may include acknowledging the harm done, working to repair relationships, and building new norms for future interactions to support the student.

I also recognize that there are positive mental health experiences under this relationship, and that relationships are bi-directional. There is an opportunity for future research to build in supports and resources to help graduate students reflect on their communication skills and needs for an advising relationship, and then develop tools to help them communicate these with their advisor to find common ground. Furthermore, there are multiple timepoint interventions can focus on, including the application and interview process for graduate school, during specific milestones, and pre- or post-candidacy. Students' research environment (i.e., advisor and research area) significantly impact metrics for success (i.e., attrition rates, citations, publication rates) over students' preparation (e.g., previous measures of academic success, prior research experience; Belavy et al., 2020). Providing processes to help students understand how these indirect environments may impact them can allow students to make informed decisions about their futures as well as work to problem solve things that are within their control.

Finally, it is important to recognize that every person has their own thoughts, perceptions, and experiences with mental health. These experiences can impact engineering graduate students' mental health directly (e.g., actions, words, behaviors, etc.) and indirectly (e.g., stigmas, biases, policies, worldview, etc.). To that end, I recommend future researchers focus on the mental health experiences of faculty and staff within engineering, both through their experiences but also in roles where they are supporting students' mental health. Faculty are fulfilling an increasingly important role of supporting students' mental health. The Boston University School of Public Health (in partnership with the Mary Christie Foundation and Healthy Minds Network) recently surveyed 1,685 faculty members across 12 institutions in the U.S. They found that 73% of faculty would welcome additional professional development support to help them support students' mental health, 21% of faculty felt a toll to their own mental health from supporting students through mentally/emotionally distressing experiences, and that almost half of faculty felt that faculty members' mental health should receive additional support and investment (Boston University School of Public Health et al., 2021). Future work can expand on these findings, looking to understand the ways the culture of engineering and higher education impacts faculty's mental health experiences, and possible interventions to better support their mental health.

4.7.5 Macrosystem (belief systems)

The macrosystem focuses on the social and cultural views that exist within any of the prior levels (i.e., individual, microsystem, mesosystem, and exosystem). To meet the call for a more diverse range of engineers, work needs to be done to assess not only the goals of engineering as a field, but how the culture and enactment of that culture supports these goals (National Academy of Engineering, 2004). Many of the mental health experiences students discussed were a result of the belief systems, ideologies, norms, and expectations that were placed on them as engineering graduate students. Generally, students who agreed with these values or were perceived to belong within engineering had positive mental health experiences, whereas those that did not had either mixed or negative experiences. Students discussed many values of the engineering education culture framework that did not align with their own worldviews (e.g., capitalistic views driving value of work done, objectivity, etc.), and how this caused tension and even hostile work environments. Research has demonstrated the value of recognition by peers to be an integral part of identity formation, which in turn impacts persistence within STEM (Carlone & Johnson, 2007; McCave et al., 2014; Owen & Rolfes, 2015; Rodriguez et al., 2018; Tonso, 2014; Trytten et al., 2015). If the culture of engineering continues to devalue or disregard the diverse set of motivations, values, and belief systems students entering engineering bring, these students will continue to have negative mental health experiences within engineering. This in turn can contribute to these students leaving engineering, and further perpetuate a cycle that excludes individuals unable or unwilling to conform.

Similarly, findings detailed a connection between students' mental health experiences and students' perceptions and beliefs towards coping mechanisms. These findings highlight avenues for future researchers to explore not only what students perceive as valid coping strategies but also examining which of these coping strategies are practical to support positive mental health experiences (and why). This in turn could be used to develop interventions to promote healthy coping mechanisms as well as suggest structural changes that could be implemented to better support positive coping mechanisms. The makeup of engineers will not change if the culture of engineering does not allow these individuals to exist within or persist through engineering.

4.7.6 Chronosystem (transition periods)

The chronosystem is focused on transition periods for both the individual and their surrounding environment. When considering the chronosystem, participants shared three major changes that occurred for them: transitioning to graduate school, changing advisors/research topics/programs, and changes brought on by the coronavirus pandemic. Most students' mental health experiences with these changes were negative as students were unsure what to expect, felt they had a deficit of knowledge in the transitions, or had difficulties adjusting to an environment that did not suit their personal and work preferences. I understand that a lot of transitions are contextual. However, many transitions, including into graduate school, expectations for coursework pre- and post-candidacy, the dissertation writing stage, and navigating post-graduation career opportunities, are standard across engineering doctoral graduate programs, with many having translational components to master's programs. This study and existing work have demonstrated that transition periods, regardless of the cause, can be a very negative mental health experiences for students (Bahnson et al., 2019; Healthy Minds Network & American College Health Association, 2020; Young Minds, 2020). Therefore, future work should explore the multiple transitions engineering graduate students face and what differentiates outcomes of students' persistence through these transitions. Understanding this can help identify interventions and/or policy changes that can be implemented to increase students' persistence within engineering.

4.8 Conclusion

This study first sought out to understand the range of mental health experiences (framed as emotional experiences) of engineering graduate students at one HWI. By leveraging the photovoice method, I explored the experiences of students from a range of engineering disciplines, backgrounds, identities, and self-reported mental health measures (i.e., depression, anxiety, and flourishing). Participants shared a range of positive, negative, and mixed (i.e., both positive and negative) mental health experiences. These experiences were sorted by participants into eight groupings that spanned across five of the six themes from data analysis. These themes were found to be connected, often building on one another. Findings from this work suggest that positive mental health experiences were aligned with healthy coping mechanisms, whereas negative mental health experiences came from experiences where students engaged in unhealthy coping mechanisms and/or were unable to utilize their preferred healthy coping mechanism. Mixed mental health experiences were often the result of experiences that differed based on students' backgrounds, experiences, and/or identities.

The second goal of this work was to understand how, if at all, the culture of engineering impacted engineering graduate students' mental health experiences. I found conclusively that the culture of engineering does have an impact. Furthermore, by leveraging Bronfenbrenner's ecological systems theory, I found that these experiences impact students within every aspect of their life. There were shared ways the culture impacted students' mental health that included positive and negative experiences. However, on average, students' mental health experiences were negatively impacted by the culture of engineering. Furthermore, this work demonstrates that dimensions and themes under this culture make assumptions on the backgrounds, beliefs, experiences, identities, and values engineering graduate students should hold, and punishes or pushes out those who do not align with these assumptions.

If we are to come together as a community within engineering, we must work to support the range of students' mental health experiences, working to support positive ones and mitigate or remove negative ones. This requires a cultural change. Engineers at all levels (e.g., industry, national policy makers, faculty, students, etc.), must critically reflect on the norms, values, and assumptions we make, and do the work and become intentional in aligning our actions with our intentions.

Chapter 5 Exploring the Relationship Between Engineering Culture and Graduate Students' Mental Health[5]

In this chapter, I explore the relationship between engineering graduate students' self-reported mental health and the culture of engineering. I do so by leveraging data from a national survey across three academic years (2018-2021). The following chapter begins by providing an overview of the motivation for this study and the guiding research questions. I then detail the data source and the measures used in this study. This includes describing how I used a theoretical framework to guide the selection of measures used as proxies for the culture of engineering and my choice to include demographic covariates. Following this I will detail the study sample and the analytical approach (i.e., descriptive/bivariate statistics, regression analysis) used to answer the research questions. The analytical approach will also explain the choice to use a nested modeling approach in the regression analyses. After the methods section I will discuss the limitations of this study, the findings, and the significance of these findings before I summarize the key points and offer suggestions for future work. Findings will demonstrate that measures of mental health for engineering graduate students are getting worse and that there is a significant relationship between proxies of engineering graduate students' mental health and the culture of engineering.

Portions of the chapter are modified and adapted from [5]Bork, S.J., Young, N., & Mondisa, J.-L. (2022). Exploring the Relationship Between Culture and Science, Engineering, and Mathematics Graduate Students' Mental Health (Full Paper). *Proceedings of the Annual American Society of Engineering Education (ASEE) Conference*, July 26-29, 2022. Minneapolis, MN.

5.1 Introduction

There has been a growing crisis concerning students' mental health in the United States (U.S.) with mental health problems on the rise. A study lead by Sarah Lipson in 2019 highlighted rising mental health diagnoses (21.9% to 35.5%), services utilization (18.7% to 33.8%), and student-reported suicidal ideation (5.8% to 10.8%) over a ten-year span of 2007-17 (Lipson, Lattie, et al., 2019). This is more than double to the national average in 2019, with roughly 4.7% of adults 18 or older reporting seriously considering suicide (Substance Abuse and Mental Health Services Administration, 2020; U.S. Department of Commerce, 2020). In addition, a recent report by the National Academies of Science, Engineering, and Medicine (NASEM) titled *Mental Health, Substance Use, and Wellbeing in Higher Education: Supporting the Whole Student* highlighted three major concerns impacting students' mental health in the U.S.: the COVID-19 pandemic, the rise in unemployment and instability in the U.S. economy, and increased awareness of anti-Blackness and racism (NASEM, 2021). At the same time, higher education institutions have been struggling to keep up with the increase demand for mental health services (LeViness et al., 2017, 2019). This collective evidence calls for concerted efforts to address mental health concerns in higher education. However, most research has focused on examining the mental health experiences of an aggregate sample of undergraduate and graduate students despite research illustrating that the prevalence of experiencing psychological distress and having or developing a mental health problem is higher for graduate students compared to same age, highly-educated peers ((Hefner & Eisenberg, 2009; Hunt & Eisenberg, 2010; Lipson, Lattie, et al., 2019; Satinsky et al., 2021). Research studies that do not separate out graduate students fail to account for the differences between students' mental health experiences in graduate degree programs and associate and baccalaureate programs, and the factors that can influence their mental health. Graduate students have different academic demands (e.g., more focus on independent research and communicating work), often inform their choices based on their past experiences in their undergraduate programs and tend to be older (Wyatt & Oswalt, 2013). Furthermore, the social and cultural influence of graduate degree programs and disciplines is stronger as a large focus of graduate programing is to indoctrinate students into this discipline (Hyun et al., 2007; Levecque et al., 2017).

By analyzing data collected over the past three academic years on engineering graduate students as part of the Healthy Minds Networks' (HMN) Healthy Minds Study, I add to the literature and understanding on engineering graduate student mental health (The Healthy Minds Network, 2023). Specifically, this study was driven by two goals. The first was to understand the state of engineering graduate student mental health over the past three academic years, measured through the proxies of *depression*, *suicidal ideation*, *anxiety*, and *flourishing*. The second goal was to understand what role the culture of engineering graduate students' program has on students' self-reported mental health. The culture of engineering was examined using proxies for dimensions/themes of the culture of engineering education framework (CEEF) by Godfrey and Parker (2010). Given the known systemic issues that lead to differences in mental health measures when assessed at the demographic level (detailed in Chapter 2 of this dissertation), the demographics of *gender*, *race*, *international student status*, *degree*, and *year in program* were included in analysis. This culminated in two research questions, the first to understand the context of mental health over three recent academic years (2018-19, 2019-20, and 2020-21) and the second to explore these relationships:

(1) How has the mental health of engineering graduate students, measured by *depression*, *suicidal ideation*, *anxiety,* and *flourishing*, changed over 2018-2021?

(2) What role, if any, does the culture of engineering have on engineering graduate students' self-reported mental health measures of *depression*, *suicidal ideation*, *anxiety*, and *flourishing*, when accounting for intuitional differences and students' *gender*, *race*, *international student status*, *degree*, and *year in program*?

5.2 Methodology

The following sections discuss the research approach performed to answer the research questions. First, an overview of the data source is provided before discussing the four dependent variables (outcomes of interest), 11 categorial independent variables (cultural covariates), and five control variables (demographic covariates). Then, the sample for this study and analytical approach are discussed.

5.2.1 Data Source

Data for this study comes from the Healthy Minds Network's (HMN) Healthy Minds Study (HMS; The Healthy Minds Network, 2023). This is a national survey that attempts to collect population level data from each institution participating in the study (i.e., by randomly surveying 4,000 students or the entire student population, whichever was smaller. In addition, the survey applies weights to survey responses to get a representative sample (i.e., non-response weights estimated using a logistic multivariable regression from administrative data on gender, race/ethnicity, academic level, and grade point average and then applied to each students' responses). Students are recruited via email and completed a survey that asks them to reflect on experiences up to 12 months prior to the time the survey was administered. Participants received financial compensation for participating in the study. The survey itself is composed of 19 modules. Three of those modules are core modules and are presented to all study participants.

The remaining modules are opted into where the institution working with the HMN group opts into the modules they want, with some restrictions based on cost and total number of modules permitted (The Healthy Minds Network, 2023).

5.2.2 Outcomes of Interest

There were four outcomes of interest selected for this study (detailed in Table 5-1). These four dependent measures were selected as they served as proxies to assess engineering graduate students' self-reported mental health. *Anxiety* was measured using self-reported responses to the General Anxiety Disorder 7 (GAD-7) scale (Spitzer et al., 2006). *Anxiety* for this study was used as a composite score, summing responses to seven items on the GAD-7 scale, scored from zero (not at all) to three (nearly every day). This score can then be grouped into severity of anxiety: 0-4 minimal anxiety, 5–9 mild anxiety, 10–14 moderate anxiety, and 15–21 severe anxiety. *Depression* was measured using the Raw Patient Health Questionnaire score (0-27) from the

Table 5-1. Outcome measures included in this study.

Measure	Measure Details	Scale
anxiety (GAD-7)	General Anxiety Disorder (GAD-7) score; self-reported measure for severity of anxiety; summative score across 7 items scored 0 (not at all) to 3 (nearly every day)*	0–4: minimal anxiety 5–9: mild anxiety 10–14: moderate anxiety 15–21: severe anxiety
depression (PHQ-9)	Raw Patient Health Questionnaire (PHQ-9) score; self-reported measure for severity of depression; summative score across 9 items scored 0 (not at all) to 3 (nearly every day)*	0-4: minimal depression 5-9: mild depression 10-14: moderate depression 15-19: moderately severe depression 20-27: severe depression
flourishing (positive mental health)	Psychological Well-Being (PWB) scale; self-reported views on areas including relationships, self-esteem, purpose/meaning, and optimism; summative score across 8 items scored 1 (strongly disagree) to 7 (strongly agree)*	Scores range from 8 (lowest) to 56 (highest); A higher score indicates a person with many psychological resources and strengths
suicidal ideation	In the past year, did you ever seriously think about attempting suicide?	0=No 1=Yes

*Notes: Appendix C provides details on survey items

Patient Health Questionnaire (PHQ; Kroenke et al., 2001; Pfizer Inc., 1999; Spitzer et al., 1999). This score comes from totaling the score of nine items scaled zero (not at all) to three (nearly every day), asking participants at the time of the survey to reflect on the past two weeks as they pertain to depressive symptoms. The PHQ-9 score is grouped based on depressive symptom severity: 0-4 minimal depression, 5-9 mild depression, 10-14 moderate depression, 15-19 moderately severe depression, and 20-27 severe depression (Pfizer Inc., 1999). *Flourishing* was measured using the Psychological Well-Being scale given the intent to assess measures of positive mental health (Diener et al., 2009; Oishi & Biswas-Diener, 2009). This scale is created by totaling eight items, each with a total from one to seven (strongly disagree to strongly agree) for a cumulative range of 8 to 56. Unlike the previous instruments, this scale does not have categories; simply, the higher the reported composite number, the higher demonstrated positive mental health. *Suicidal ideation* was used to measure if the respondent has ever seriously considered suicide in the past year at the time of the survey using a dichotomous yes/no question. Details on these instruments are detailed in Appendix C.

5.2.3 Cultural Covariates

There were 11 covariates selected for this study. The selection of these covariates was guided by Godfrey & Parker's Culture of Engineering Education Framework (CEEF; 2010) and informed by a recent application of this framework. CEEF was developed to understand the culture of engineering, goals of engineering as a discipline, and how engineers saw these goals being achieved (Godfrey & Parker, 2010). Godfrey and Parker defined six dimensions of engineering education (i.e., an engineering way of thinking, an engineering way of doing, being an engineer, acceptance of difference, relationships, and relationship to the environment), each with a subset of themes for how this dimension is present within the culture of engineering. Table 5-2 defines

Table 5-2. The definitions and themes of Godfrey & Parker's Culture of Engineering Education Framework (CEEF; Godfrey & Parker, 2010)

Dimension	Definition	Themes
An Engineering Way of Thinking	Unique ways of knowing or conceptualizing information as an engineer	• Math is infallible, innocent, and/or pure • Strong prevalence of visual communication • Problem solving and design • “Best” not “right” answers • Objectiveness in math and science
An Engineering Way of Doing	Beliefs and/or assumptions on how teaching and learning occurs within engineering education	• Hardness • Take it • Approach problem solving using a toolkit • Professional development is conditionally valued • Cooperation and Competition • Education is used for credentials • Time is a resource to be managed
Being an Engineer	Common attributes and/or attitudes associated with being an engineer	• Can-do attitude • Think in bullet points • Stereotypes • All or nothing • Being one of the “guys” • Prideful in being an engineer
Acceptance of Difference	Considering the homogeneity and/or diversity of thoughts and/or values within engineering	• Homogeneity • Conditional acceptance • First impressions • Prove yourself
Relationships	What relationships exist and/or the appropriate ways relationships are established and maintained within engineering	• Collaborative • Mates • Student – faculty interactions
Relationship to Environment	Assumptions and beliefs held regarding engineering education’s operation within several environments, including a campus environment, an institutional environment, the broader environment of higher education, engineering as a profession, and the cultural landscape of the geographic location (e.g., politics, economics, etc.)	• Situated within several embedded ecosystems • Desire for autonomy and independence • Inherent oversight

these dimensions and lists their respective themes. Findings from my recent photovoice study (Chapter 4) leveraged CEEF to understand how, if at all, the culture of engineering impacted engineering graduate students’ mental health experiences. My results demonstrated that overall, although there were positive mental health experiences related to the culture of engineering (examined through the dimensions/themes of CEEF), most were negative.

The research team sought to find items representative of each theme within the six dimensions of CEEF. Potential survey items were mapped from the HMS to serve as proxies for the CEEF themes (as available). I then met with three other researchers (a senior doctoral student, a doctoral student, and a research scientist) with over six years of collective expertise leveraging this framework (using qualitative, quantitative, and mixed methods research approaches) to validate the mapping of the survey items. Items that had at least one other researcher agree with the alignment and had no researcher disagree with the alignment were then explored quantitatively. There was a shortlist of items across five of the six dimensions of CEEF (all but an engineering way of thinking). This shortlist of items was examined in R to determine if engineering graduate students had been given the modules the items were a part of across the three years of data (i.e., determine if the items were systemically missing), as well as the number of responses to the item across the three academic years (i.e., maximum sample size).

As discussed previously, for the HMS, questions had the potential to come from 16 of the opt-in modules that could change at each institution. Several items were dropped as they were systemically missing from the most (>70%), if not all, the population (i.e., participants did not have the item on the survey they took). Finally, returning to the framework, only two of the dimensions had multiple survey items to serve as proxies for themes within analysis (i.e., higher saturation of data). This resulted in 11 survey items across two dimensions of CEEF: an engineering way of thinking and acceptance of difference. These potential items were then reviewed once more by at least one of the external researchers before being included in the analysis. Table 5-3 details the survey items included as covariates in the analysis and the respective theme (and definition) they serve as proxies for.

Table 5-4 overviews each of these items. In addition, it provides the response categories and indicates the responses used as baselines in the regression analysis (will be discussed further in the analytical procedures section, *relationships between outcomes of interest and covariates*).

Under an engineering way of doing dimension, two themes were represented by proxy

Table 5-3. Godfrey & Parkers' Culture of Engineering Education Framework Codebook (2010)

Dimension & Themes	Definition	Themes
An Engineering Way of Doing		
Take it	Those who wish to enter the profession need to accept the difficulty and endure it, or not you are not fit for the field. Learning is equated to suffering and hardship, and being able to endure and succeed in this environment leads to a bootcamp mentality and shared sense of pride and achievement for having made it.	• degree persistence • help seeking makes you a failure • help seeking makes you lesser • keep feelings to myself
Cooperation and Competition	Competition and cooperation are accepted within engineering. Students compete for grades and opportunities. At the same time, students share in their suffering, and can choose (or at times have no other option) than to work together to survive their program.	• cooperative climate
Acceptance of Difference		
Homogeneity	There is a high degree of homogeneity within the attitudes, beliefs, norms, and values engineers are expected to hold and/or conform to. There is also an assumption the engineers have similar backgrounds and experiences (e.g., education).	• exposure to diversity • friends share race/ethnicity • friends share gender/gender identity
Conditional acceptance	Individuals are always being assessed for inclusion, and those with differences may feel it is conditional based on their ability to assimilate and/or hide/downplay what makes them different and conform to aspects under the dimension *being an engineer*.	• experiences of discrimination in the past year
First impressions	Within engineering, individuals initially form relationships based on what they perceive other's abilities are within engineering and how much they expect them to succeed and/or support their own personal success. Initial relationships are based on shared interests and backgrounds as these can be leveraged as social capital and build trust, and at the same time, are usually biased by personal biases and prejudices. Minoritized individuals find that acceptance and respect for them within the discipline to be a slow, painful, and long process as their backgrounds and experiences were atypical within engineering, accentuating them as different.	• sense of belonging • welcoming climate

items. The theme ***take it*** was represented by four items: *degree persistence*, *help seeking makes you a failure*, *help seeking makes you lesser*, and *keep feelings to myself*. These items were each scored on a scale of one to six, from one being strongly agree to six being strongly disagree. Finally, the theme ***cooperation and competition*** was represented by one item, *cooperative climate*. This item was scaled on a score of one to five, with one being very uncooperative and five being very cooperative.

The dimension acceptance of difference also had three themes represented by proxy items. The theme ***homogeneity*** was represented by three proxy items: *exposure to diversity*, *friends share race/ethnicity*, and *friends share gender/gender identity*. The first item was scored on a scale of one to six, with one being strongly agree to six being strongly disagree. The second and third items were scored on a scale from one to four, representing 0-25%, 26-50%, 51-75%,

Table 5-4. Cultural covariate measures included in this study

Measure	Measure Details	Scale
An Engineering Way of Thinking		
Take it		
degree persistence	I am confident that I will be able to finish my degree no matter what challenges I may face.	1=Strongly agree (+) 2=Agree 3=Somewhat agree 4=Somewhat disagree 5=Disagree 6=Strongly disagree (-)
help seeking makes you a failure	Most people feel that receiving mental health treatment is a sign of personal failure.	
help seeking makes you lesser	Most people think less of a person who has received mental health treatment.	
keep feelings to myself	When I feel depressed or sad, I tend to keep those feelings to myself.	
Cooperative climate		
cooperative climate	Using the scale below, please rate the overall climate at [school name] over the past 12 months: Cooperative - Uncooperative	1=Very uncooperative (-) 2=Somewhat uncooperative 3=Neither uncooperative nor cooperative 4=Somewhat cooperative 5=Very cooperative (+)
Acceptance of Difference		
Homogeneity		
exposure to diversity	At my school, I have been exposed to diverse opinions, cultures, and values.	1=Strongly agree (+) 2=Agree 3=Somewhat agree 4=Somewhat disagree 5=Disagree 6=Strongly disagree (-)
friends share race/ethnicity	What percentage of your friends share your racial/ethnic identity?	1=0-25% (-) 2=26-50% 3=51-75% 4=76-100% (+)
friends share gender/gender identity	What percentage of your friends share your gender/gender identity?	
Conditional acceptance		
experiences of discrimination in the past year	In the past 12 months, have you been treated unfairly at your school because of any of the following: your race/ethnicity, cultural background, gender, sexual orientation, and/or other (please specify)?	1=Never (+) 2=Once in awhile 3=Sometimes 4=A lot 5=Most of the time 6=Almost all of the time (-)
First impressions		
sense of belonging	I fit in well at my school.	1=Strongly agree (+) 2=Agree 3=Somewhat agree 4=Somewhat disagree 5=Disagree 6=Strongly disagree (-)
welcoming climate	Using a scale of 1-5, please rate the overall climate at [school name] over the past 12 months on the following: Welcoming - Not welcoming	1=Not Welcoming (-) 2=Somewhat not welcoming 3=Neither not welcoming nor welcoming 4=Somewhat welcoming 5=Welcoming (+)

Notes: (-) indicates it is the baseline response for negative mental health outcome models (i.e., anxiety, depression, and suicidal ideation) and (+) indicates it is the baseline response for the positive mental health outcome model (i.e., flourishing) and 76-100% respectively. The theme ***conditional acceptance*** was represented by the proxy item *experiences of discrimination in the past year*. This item was scored on a scale of one to six, with one being never (experienced) and six being almost all of the time (experienced). The theme ***first impressions*** was represented by two proxies: *sense of belonging* and *welcoming climate*. The first item was scored on a scale of one to six, from one being strongly agree to six being strongly disagree. The second item was scaled on a score of one to five, with one being not welcoming and five being welcoming.

5.2.4 Demographic Covariates

In addition to the cultural covariates, I included five demographic covariates in our analysis: *gender*, *race/ethnicity*, *international student status*, *degree program*, and *year in program*. Response options for *gender* were consolidated to female, male, or neither female nor male. Response options for *race/ethnicity* were African American or Black; Asian or Asian-American; Hispanic or Latino, Middle Eastern, Arab, or Arab American; White or Caucasian; and multi-racial or other. The measure *international student status* was coded for yes (value of one) or no (value of zero). The *degree program* responses were limited to master's or doctoral, and the *year in program* responses were coded from one to seven, with one representing first year and seven representing seven (or more) years.

5.2.5 Sample

For this study, our analysis used data provided on engineering graduate students from 2018-2019, 2019-2020, and 2020-2021. There was a total of 1,519, 2,954, and 3,101 participants in these data sets, respectively. However, as discussed previously, several of the survey items being used in analysis come from opt-in modules that can vary at each institution. After removing responses that were systematically missing (i.e., items that had no survey responses / were not included in any of the surveys participants took), there were a total of 234, 1,857, and 1,473 responses, respectively. These samples were the data used in analysis, for a total of 3,564 responses from 44 institutions (note, some institutions may be repeated across the three years).

Demographics for participants for each academic year and collectively for the 3,564 respondents are presented in Table 5-5. As detailed, I included the demographics of gender, race, international student status, degree, and students' year in their program. For all demographic variables, any response categories that were less than 1% of the total data in aggregate form (i.e., 2018-21 data) were not presented to protect study participants from being identified. Due to this,

Table 5-5. Demographics for study participants by academic year and aggregated

Demographic Measure	**Annual Data**			**Aggregate Data**
	2018-2019 N (%)	**2019-2020 N (%)**	**2020-2021 N (%)**	**2018-2021 N (%)**
Gender	234 (100)	1,857 (100)	1,473 (100)	3,564 (100)
Female	88 (38)	626 (34)	559 (38)	1,273 (36)
Male	143 (61)	1,212 (65)	892 (61)	2,247 (63)
Neither Female nor Male	3 (1)	19 (1)	22 (1)	44 (1)
Race/Ethnicity	234 (100)	1,857 (100)	1,473 (100)	3,564 (100)
African American/Black	5 (2)	67 (4)	42 (3)	114 (3)
Asian/Asian-American	90 (38)	883 (48)	748 (51)	1,721 (48)
Hispanic/Latino	9 (4)	103 (6)	50 (3)	162 (5)
Middle Eastern, Arab, or Arab American	11 (5)	103 (6)	79 (5)	193 (5)
White or Caucasian	99 (42)	651 (35)	437 (30)	1,187 (33)
Multi-Racial or Other	20 (9)	50 (3)	117 (8)	187 (5)
International Student	234 (100)	1,857 (100)	1,473 (100)	3,564 (100)
No	132 (56)	892 (48)	622 (42)	1,646 (46)
Yes	102 (44)	960 (52)	850 (58)	1,912 (54)
Other/Not Applicable/Missing	0	5 (0)	1 (0)	6 (0)
Degree Program	234 (100)	1,857 (100)	1,473 (100)	3,564 (100)
Master's	80 (34)	985 (53)	879 (60)	1,944 (55)
PhD	154 (66)	872 (47)	594 (40)	1,620 (45)
Year in Program	234 (100)	1,857 (100)	1,473 (100)	3,564 (100)
First Year	73 (31)	777 (42)	491 (33)	1,341 (38)
Second Year	56 (24)	536 (29)	542 (37)	1,134 (32)
Third Year	40 (17)	238 (13)	159 (11)	437 (12)
Fourth Year	26 (11)	183 (10)	162 (11)	371 (10)
Fifth Year	20 (9)	75 (4)	68 (5)	163 (5)
Sixth Year	6 (3)	25 (1)	24 (2)	55 (2)
Seventh Year (+)	7 (3)	14 (1)	20 (1)	41 (1)
Other/Not Applicable/Missing	6 (3)	9 (0)	7 (0)	22 (1)

categories in some of the variables were consolidated or removed. For example, the measure *gender* was coded to be female, male, or neither female nor male, which included all other gender identities. Likewise, American Indian/Alaskan Native and Pacific Islander responses were grouped into another category along with students who selected multiple races. As has been pointed out elsewhere, aggregating students may obscure important distinctions between groups (Shafer et al., 2021; Teranishi, 2007). For students who responded to the degree being both a master's and doctoral degree, they were recoded as doctoral degrees given embedded master's degrees in doctoral programs are common in the U.S.

5.2.6 Analytical Procedures

There were three stages of analysis completed: (1) obtaining descriptive statistics and central tendencies for each measure, (2) determining trends in the measures over the past three academic years, and (3) determining what relationships, if any, exist between the covariates and each outcome of interest. Analysis was completed in R 4.2.3, a statistical software program. The remainder of this section details these three stages of analysis. As these results and methods build upon one another, the following section will present a brief overview of the procedure followed to generate the results with the Results section detailing the findings.

5.2.6.1 Descriptive Statistics

The first step before analyzing the data was to explore the data by generating descriptive statistics and central tendency for each of the outcomes of interest and explanatory variables. To do so, I determined the range of values, mean, standard deviation, and variance for the measures, both for the individual academic years and collectively (provided in Table 5-7 later).

5.2.6.2 Trends Over Past Three Academic Years

To assess trends in the data over the 3 years, I ran an analysis to test whether there was a statistically significant difference in means via Welch's two-sided t-tests (using Equations 1a, 1b, and 1c). This was done as I did not want to assume directionality of the trends. A Welch's t-test was elected as the assumption of equal variances was not met for all measures (detailed in Table 5-7 in the findings section). The t-tests were used to compare each academic year against the other two for each of the eight measures, or 24 t-tests. Results from these t-tests are detailed in Table 5-8 in the findings section.

$$\hat{\sigma}_{\bar{y}_1-\bar{y}_2} = \sqrt{\frac{s_1^2}{n_1}+\frac{s_2^2}{n_2}} \;,\;\; \hat{t} = \frac{(\bar{y}_1-\bar{y}_2)-H_0}{\hat{\sigma}_{\bar{y}_1-\bar{y}_2}} \;,\;\; df_t = n_1 + n_2 - 2 \qquad \text{(1a, 1b, \& 1c)}$$

$\hat{\sigma}_{\bar{y}_1-\bar{y}_2}: standard\ deviation\ of\ the\ difference\ in\ means\ between\ two\ samples$

$\bar{y}: mean\ for\ sample\ y$

$s_i^2: variance\ for\ sample\ i$

$n_i: number\ of\ observations\ for\ sample\ i$

$\hat{t}: t - statistic$

$H_0: null\ hypothesis$

$df_i: degrees\ of\ freedom\ for\ sample\ i$

Additionally, as a two-sided t-test was used, I also calculated the difference in means for each t-test performed to help provide insight into the possible directionality of the difference. To do so, I subtracted the mean of the chronologically earlier academic year from the mean of the chronological later academic year (Equation 2).

$$difference\ in\ means < measure >_{Year2-Year1} = \overline{< measure >}_{Year2} - \overline{< measure >}_{Year1} \qquad (2)$$

5.2.6.3 Generating the Data used in the Models

Before exploring the relationships between the outcomes of interest and covariates, I first needed to generate our data set and address missing data. I first worked to remove any data that was systemically missing. This allowed me to remove all responses that were systematically missing (i.e., institutions that did not include all the items used in the analysis on the survey they administered to students). This resulted in a total of 3,564 responses from 44 institutions (two in 2018-19, 17 in 2019-20, and 25 in 2020-21).

Second, I wanted to determine if any items broke the assumption of independence in the measures. To examine this, I sought to determine if any of the items were highly correlated (>0.6). I ran pairwise complete correlation to generate a heat map between all outcomes of interest, the cultural covariates, and the demographic covariates (detailed in Appendix C, Figure C-4). Examining the heat map, I found that there was one case that was higher than this. This with a correlation of 0.8 between *cooperative climate* and *welcoming climate*. These two items come from a five-item survey that examines an environment's climate, and I believe this correlation comes from these items measuring similar yet distinct elements of climate. Therefore, I chose to include both items.

Finally, I worked to address data missing not systemically. At this stage, I assumed data missing was missing completely at random as I had confirmed that the survey items were administered at students' institutions. I imputed this missing data using the mice package in R (van Buuren & Groothuis-Oudshoorn, 2011). The number of imputed data sets was set to 20 (the high end of the recommended range from van Buuren, 2018) based on the structure of the missing data. All other options were set to default.

5.2.6.4 Relationships Between Outcomes of Interest and Covariates

To examine the relationships between the outcomes of interest and cultural covariates, I ran analysis using on the aggregate data for engineering graduate students from 2018-2021, controlling for the demographic covariates (as detailed in Figure 5-1) . The reported values for the three interval outcomes of interest were used (i.e., depression, anxiety, and flourishing scale scores), with suicidal ideation being coded as dichotomous. The cultural and demographic covariate measures were used in either categorical or dichotomous forms. As a result, four models were run, each focusing on a different outcome of interest (i.e., Model 1 for *anxiety*, Model 2 for *depression*, Model 3 for *flourishing*, and Model 4 for *suicidal ideation*), with the model type varying based on the outcome of interests' variable type.

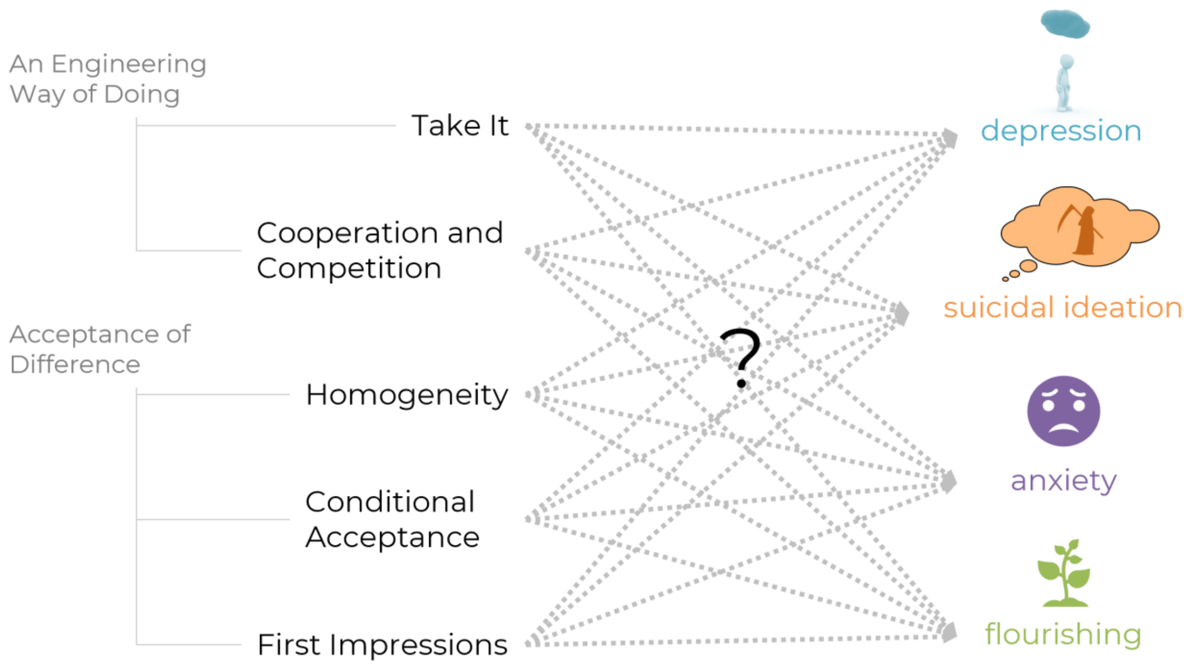

Figure 5-1. Detailing the high level regression analysis ran for each of the four outcomes of interest against the dimension/themes of CEEF (not included, demographic covariates).

For each regression model in this study, analysis is conducted by comparing responses to baseline group. I selected the baseline comparison group to be the responses that would be expected to strongly endorse the outcome of interest. As Model 3 (*flourishing*) had a metric of positive mental health, the baseline measures that would be expected to endorse this measure would be on the opposite response as those used to endorse negative mental health outcomes of interest in Models 1, 2, and 4.

Table 5-4, as previously discussed, indicated the baseline responses used in the negative mental health measure models (i.e., *anxiety, depression,* and *suicidal ideation*) as well as the positive mental health model (i.e., *flourishing*).

In terms of the demographic variables, a first-year White male domestic student in a master's program was elected as the baseline group (i.e., race = White, gender = male, year = first, international student = no, degree = master's). I acknowledge that these choices are arbitrary though previous analysis of older Healthy Minds Network data has used similar choices (Posselt, 2021).

As I examined the role of culture on mental health measures, I acknowledge that there may be differences based on the institution students are at (and respective institutional culture they experience). I therefore accounted for institution type by nesting our analytical models by institution.

Models 1, 2, and 3 had outcomes of interests that were interval measures (i.e., *anxiety*, *depression*, and *flourishing* scores). As a result, ordinary least squares regression (i.e., multiple linear regression) models were estimated to understand the difference between the covariates and the respective outcomes of interest for each model. For each categorical covariate or demographic measure, each response option category was run as dummy dichotomous variables in the linear regression model, omitting the baseline option as detailed above. Equation 3a details the regression equation used for modeling the covariates against negative mental health interval outcomes of interest (i.e., *anxiety* and *depression*), with equation 3b detailing the regression equation for modeling the covariates for *flourishing*, the positive mental health interval outcome of interest:

$$\begin{aligned}\widehat{anxiety}_i \; OR \; \widehat{depression}_i = \; & a + b_{DP1}(degree\ persistence)_i + \cdots + \; b_{DP5}(degree\ persistence)_i \\ & + b_{HSF2}(help\ seeking\ failure)_i + \cdots + \; b_{HSF6}(help\ seeking\ failure)_i \\ & + b_{HSL2}(help\ seeking\ lesser)_i + \cdots + \; b_{HSL6}(help\ seeking\ lesser)_i\end{aligned} \tag{3a}$$

$$
\begin{aligned}
&+ b_{FS2}(feelings\ self)_i + \cdots + \ b_{RFS6}(feelings\ self)_i \\
&+ b_{ED1}(exposure\ diversity)_i + \cdots + \ b_{ED5}(exposure\ diversity)_i \\
&+ b_{SB1}(sense\ of\ belonging)_i + \cdots + \ b_{SB5}(sense\ of\ belonging)_i \\
&+ b_{CC2}(cooperative\ climate)_i + \cdots + \ b_{CC5}(cooperative\ climate)_i \\
&+ b_{FRE2}(friends\ share\ race/ethnicity)_i + \cdots + \ b_{FRE4}(friends\ share\ race/ethnicity)_i \\
&+ b_{FG2}(friends\ share\ gender)_i + \cdots + \ b_{FG4}(friends\ share\ gender)_i \\
&+ b_{D1}(experiences\ of\ discrimination)_i + \cdots + \ b_{D5}(experiences\ of\ discrimination)_i \\
&+ b_{WC2}(welcoming\ climate)_i + \cdots + \ b_{WC5}(welcoming\ climate)_i \\
&+ b_{GEN1}(gender)_i + b_{GEN3}(gender)_i \\
&+ b_{RACE1}(race)_i + \cdots + \ b_{RACE4}(race)_i \ + \ b_{RACE6}(race)_i \\
&+ b_{INT1}(international\ student)_i \\
&+ b_{DEG1}(degree)_i \\
&+ b_{YR2}(year)_i + \cdots + \ b_{YR6}(year)_i \ + \ b_{YR7}(year)_i \\
&+ nest(institution\ identifier) \\
&+ \epsilon rror
\end{aligned}
$$

$$
\begin{aligned}
\widehat{flourishing_i} = \ & a + b_{DP2}(degree\ persistence)_i + \cdots + \ b_{DP6}(degree\ persistence)_i \\
&+ b_{HSF1}(help\ seeking\ failure)_i + \cdots + \ b_{HSF5}(help\ seeking\ failure)_i \\
&+ b_{HSL1}(help\ seeking\ lesser)_i + \cdots + \ b_{HSL5}(help\ seeking\ lesser)_i \\
&+ b_{FS1}(feelings\ self)_i + \cdots + \ b_{RFS5}(feelings\ self)_i \\
&+ b_{ED2}(exposure\ diversity)_i + \cdots + \ b_{ED6}(exposure\ diversity)_i \\
&+ b_{SB2}(sense\ of\ belonging)_i + \cdots + \ b_{SB6}(sense\ of\ belonging)_i \\
&+ b_{CC1}(cooperative\ climate)_i + \cdots + \ b_{CC4}(cooperative\ climate)_i \\
&+ b_{FRE1}(friends\ share\ race/ethnicity)_i + \cdots + \ b_{FRE3}(friends\ share\ race/ethnicity)_i \\
&+ b_{FG1}(friends\ share\ gender)_i + \cdots + \ b_{FG3}(friends\ share\ gender)_i \\
&+ b_{D2}(experiences\ of\ discrimination)_i + \cdots + \ b_{D6}(experiences\ of\ discrimination)_i \\
&+ b_{WC1}(welcoming\ climate)_i + \cdots + \ b_{WC4}(welcoming\ climate)_i \\
&+ b_{GEN1}(gender)_i + b_{GEN3}(gender)_i \\
&+ b_{RACE1}(race)_i + \cdots + \ b_{RACE4}(race)_i \ + \ b_{RACE6}(race)_i \\
&+ b_{INT1}(international\ student)_i \\
&+ b_{DEG1}(degree)_i \\
&+ b_{YR2}(year)_i + \cdots + \ b_{YR6}(year)_i \ + \ b_{YR7}(year)_i \\
&+ nest(institution\ identifier) \\
&+ \epsilon rror
\end{aligned} \tag{3b}
$$

In Model 4, the outcome of interest was whether the individual had experienced *suicidal ideation* in the past year, measured as a dichotomous variable. To assess this, a binomial logistic regression model (logit model) was used (Bork & Mondisa, 2019; Henderson, 2017; Henderson et al., 2018). Probabilities are the basis for these models. The odds that an event occurring was calculated by figuring out the probability of an event occurring (p) and dividing this by (1-p), or the probability of the event *not* occurring (Equation 4). An example for this study would be the probability that an engineering graduate student experiences any level of *suicidal ideation* in the past year.

$$\text{odds} = \frac{p}{1-p} \tag{4}$$

A logit model is expressed as a linear combination of the independent (explanatory) variables, where a unit change in an independent variable is related to a change in the log-odds of the dependent variable (Equation 5).

$$\ln\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots \tag{5}$$

To interpret these results, I transform this equation of log-odds to be expressed in terms of off ratios (Equation 6).

$$\frac{p}{1-p} = e^{\alpha} + e^{\beta_1 x_1} + e^{\beta_2 x_2} + e^{\beta_3 x_3} + \cdots \tag{6}$$

The large benefit from doing this is that odds ratios are simpler to interpret (Theobald et al., 2019). That is, an odds ratio less than one represents a decrease in the odds of an outcome relative to the baseline outcome and an odds ratio greater than one represents an increase in the odds of an outcome relative to the baseline outcome (Theobald et al., 2019).

5.2.6.5 Are these findings unique to engineering graduate students?

In this study, I am exploring the relationship between the culture of engineering and engineering graduate students' self-reported mental health. However, there is a possibility that findings from this analysis are not unique to this population. The scope of this study is not to examine the mental health trends in all graduate students. Rather, the goal of this analysis is to examine if the relationships between the culture of engineering and students' self-reported mental health measures are unique to this population, and therefore, supporting a uniqueness in this relationship.

In practicality, this means that I repeated the analyses exploring the relationship between the outcomes of interest and demographic and cultural covariates using a larger, all graduate student population that included engineering students. That is, I also ran these analyses exploring the relationship between the covariates and outcomes of interest (including data preparation methods) on a larger sample of all graduate students' sample from 77 institutions (note, some institutions may be repeated across the three years). If the relationship was not unique to engineering graduate students, then the results from the analysis on engineering graduate students should mirror those in the larger graduate student analysis. I used the same data preparation methods across the same academic years 2018-2021 (n=28,230). Table 5-6 details the demographics for this sample, by both the academic years and in aggregate form.

Table 5-6. Demographics for all graduate students by academic year and aggregated

Demographic Measure	Annual Data			Aggregate Data
	2018-2019 N (%)	2019-2020 N (%)	2020-2021 N (%)	2018-2021 N (%)
Gender	3,526 (100)	10,987 (100)	13,717 (100)	28,230 (100)
Female	2,426 (69)	7,029 (64)	9,465 (69)	18,920 (67)
Male	1,023 (29)	3,756 (34)	3,995 (29)	8,774 (31)
Neither Female nor Male	77 (2)	202 (2)	257 (2)	536 (2)
Race/Ethnicity	3,526 (100)	10,987 (100)	13,717 (100)	28,230 (100)
African American/Black	179 (5)	855 (8)	1,173 (9)	2,207 (8)
Asian/Asian-American	579 (16)	2,399 (22)	2,613 (19)	5,591 (20)
Hispanic/Latino	217 (6)	1,092 (10)	994 (7)	2,303 (8)
Middle Eastern, Arab, or Arab American	63 (2)	296 (3)	308 (2)	667 (2)
White or Caucasian	2,174 (62)	6,025 (55)	7,271 (53)	15,470 (55)
Multi-Racial or Other	314 (9)	320 (3)	1,358 (10)	1,992 (7)
International Student	3,526 (100)	10,987 (100)	13,717 (100)	28,230 (100)
No	2,883 (82)	8,556 (78)	11,288 (82)	22,727 (81)
Yes	636 (18)	2,404 (22)	2,420 (18)	5,460 (19)
Other/Not Applicable/Missing	7 (0)	27 (0)	9 (0)	43 (0)
Degree Program	3,526 (100)	10,987 (100)	13,717 (100)	28,230 (100)
Master's	2,063 (59)	6,906 (63)	9,443 (69)	18,412 (65)
PhD	1,463 (41)	4,081 (37)	4,274 (31)	9,818 (35)
Year in Program	3,526 (100)	10,987 (100)	13,717 (100)	28,230 (100)
First Year	1,298 (37)	4,411 (40)	5,761 (42)	11,470 (41)
Second Year	1,002 (28)	3,301 (30)	4,515 (33)	8,818 (31)
Third Year	468 (13)	1,447 (13)	1,549 (11)	3,464 (12)
Fourth Year	313 (9)	909 (8)	925 (7)	2,147 (8)
Fifth Year	179 (5)	494 (4)	494 (4)	1,167 (4)
Sixth Year	99 (3)	186 (2)	219 (2)	504 (2)
Seventh Year (+)	66 (2)	130 (1)	134 (1)	330 (1)
Other/Not Applicable/Missing	101 (3)	109 (1)	120 (1)	330 (1)

5.3 Limitations

There are several limitations for this study. The first is that there is a possibility for a student to be represented up to three times. This is because students may have taken the survey in each offering as institutions may offer the survey more than once. However, I chose to include the data given the increase in responses across years, the use of randomized sampling at institutions (i.e., those with more than 4,000 students), and time between surveys and potential change in responses from individuals. Furthermore, there was no way for us to determine participant duplication or institution duplication without restricting the data to the final year, which was not desirable for this study.

The measures I used to assess mental health and program climate are also limitations. Because I used an existing survey instrument, there is not a perfect alignment in the item mapping and CEEF framework. As a result, there may be alternative underlying constructs being measured when using these proxies. Furthermore, due to the nature of how the survey was administered and data collected, I was unable to map many of the dimensions and themes from CEEF. Applications to the larger cultural framework guiding this study and culture of engineering this analysis sought to assess is limited by this.

Directly related to this is the second limitation, in that the 2019 coronavirus pandemic's onset began and was in full effect during the second and third academic years when data was being collected (i.e., 2019-2020, 2020-2021). This could mean that the differences found between academic years or increased severity in self-reported mental health concerns could be a result of the pandemic, not other factors. This would also be backed by existing work that has demonstrated an increase in mental health problems amidst the pandemic in student populations (Healthy Minds Network & American College Health Association, 2020). However, I argue that the root causes of mental health problems are unlikely to change, with the pandemic serving to agitate and exacerbate these conditions as opposed to generating uniquely new mental health problems. Furthermore, I assume that in the state of the pandemic, it is unlikely that students experiencing severe mental health problems are likely to complete the survey for this study.

Related to both, because the data was anonymous, I was unable to conduct any longitudinal assessment of students and how their mental health may have been affected by the pandemic. Having such data would allow us to determine if students are repeated in the data and if the measures included in this study detailed variation before and after the pandemic.

Finally, because the survey is opt-in, there is likely response bias in who answers the survey. That is, those who experience mental health symptoms may be more likely to respond to a survey than those who experience no symptoms in the hopes that the inclusion of their data might lead to institutional change or improvements in support (Telford & Faulkner, 2004). In addition, because students are asked about the previous year when answering the survey, bias can exist based on what students recall and how they interpret those events (Durayappah, 2011).

5.4 Findings

The following section will detail the findings from this study to answer the research questions,

(1) How has the mental health of engineering graduate students, measured by depression, suicidal ideation, anxiety, and flourishing, changed over 2018-2021?

(2) What role, if any, does the culture of engineering have on engineering graduate students' self-reported mental health measures of depression, suicidal ideation, anxiety, and flourishing, when accounting for intuitional differences and students' gender, race, international student status, degree, and year in program?

To do so, I will first provide an overview of the descriptive statistics on the outcomes of interest and cultural covariates. I will then discuss the findings examining trends in these measures over the three academic years contained in the study sample before discussing findings on the relationship between the outcomes of interest and covariates. The latter section will first discuss findings for the engineering graduate student analyses before comparing these findings to the larger sample of all graduate students. As discussed, this is done to examine whether the relationship found is unique to engineering graduate students.

5.4.1 Descriptive Statistics

Table 5-7 details descriptive statistics for engineering graduate students from 2018-2021 (n=3,564). For *anxiety*, 46.7% (n=1,665) reported scores aligning with the category of minimal anxiety, 29% (n=1,032) reported scores aligning with the category of mild anxiety, 11% (n=392) reported scores aligning with the category of moderate anxiety, 8% (n=284) reported scores aligning with the category of severe anxiety, and 5.4% (n=191) were missing. The average anxiety score was 5.78, which coincides with the category of mild anxiety. In terms of *depression*, 31.6% (n=1,127) reported scores aligning with the category of mild depression, 15% (n=536) reported scores aligning with the category of moderate depression, 7.6% (n=271) reported scores aligning with the category of moderately severe depression, and 3.6% (n=130) reported scores aligning with the category of severe depression. The average *depression* score was a 7.18, which coincides with the category of mild depression. On the other hand, 37% (n=1320) reported scores aligning with the category of no depression and 5.1% (n=180) were missing. Participants reported an average *flourishing* score of 43.28, which corresponds to an average score of 5.41 on the individual items, or between somewhat agree and agree. In terms of

Table 5-7. Descriptive statistics for outcomes of interest and cultural covariates

Measures	Range Min	Range Max	2018-2019 N (%)	2018-2019 Mean	2018-2019 Std. Dev.	2019-2020 N (%)	2019-2020 Mean	2019-2020 Std. Dev.	2020-2021 N (%)	2020-2021 Mean	2020-2021 Std. Dev.	2018-2021 N (%)	2018-2021 Mean	2018-2021 Std. Dev.
Outcomes			234			1,857			1,473			3,564		
Anxiety	0	21	220 (100)	5.85	4.82	1764 (100)	5.51	5.03	1389 (100)	6.12	5.41	3,373 (100)	5.79	5.18
Minimal	*0*	*4*	*104* (44.4)	-	-	*902* (48.6)	-	-	*659* (44.7)	-	-	*1,665* (46.7)	-	-
Mild	*5*	*9*	*67* (28.6)	-	-	*538* (29.0)	-	-	*427* (29.0)	-	-	*1,032* (29.0)	-	-
Moderate	*10*	*14*	*36* (15.4)	-	-	*185* (10.0)	-	-	*171* (11.6)	-	-	*392* (11.0)	-	-
Severe	*15*	*21*	*13* (5.6)	-	-	*139* (7.5)	-	-	*132* (9.0)	-	-	*284* (8.0)	-	-
Depression	0	27	224 (96)	7.01	5.32	1,767 (95)	6.92	5.58	1,393 (95)	7.53	5.85	3,384 (95)	7.18	5.68
None	*0*	*4*	*86* (36.8)	-	-	*726* (39.1)	-	-	*508* (34.5)	-	-	*1,320* (37.0)	-	-
Mild	*5*	*9*	*81* (34.6)	-	-	*576* (31.0)	-	-	*470* (31.9)	-	-	*1,127* (31.6)	-	-
Moderate	*10*	*14*	*35* (15.0)	-	-	*276* (14.9)	-	-	*225* (15.3)	-	-	*536* (15.0)	-	-
Moderately Severe	*15*	*19*	*15* (6.4)	-	-	*128* (6.9)	-	-	*128* (8.7)	-	-	*271* (7.6)	-	-
Severe	*20*	*27*	*7* (3.0)	-	-	*61* (3.3)	-	-	*62* (4.2)	-	-	*130* (3.6)	-	-
Flourishing	8	56	228 (97)	43.29	8.27	1,808 (97)	43.64	9.03	1,409 (96)	42.81	9.50	3,445 (97)	43.28	9.18
Suicidal Ideation	0	1	221 (94)	0.054	0.23	1,772 (95)	0.062	0.24	1,404 (95)	0.058	0.23	3,397 (95)	0.0598	0.24
Yes	*1*	*1*	*12* (5.1)	-	-	*109* (5.9)	-	-	*82* (5.6)	-	-	203 (5.7)	-	-
Cultural Covariates														
An Engineering Way of Thinking														
degree persistence	1	6	233 (100)	1.95	1.12	1,837 (99)	1.74	0.99	1,447 (98)	1.83	1.07	3,517 (99)	1.79	1.03
help seeking makes you a failure	1	6	102 (44)	2.61	1.19	512 (28)	2.62	1.21	604 (41)	2.59	1.16	1,218 (34)	2.61	1.18
help seeking makes you lesser	1	6	102 (44)	3.81	1.25	512 (28)	3.84	1.34	607 (41)	3.77	1.30	1,221 (34)	3.81	1.32
keep feelings to myself	1	6	103 (44)	2.93	1.37	512 (28)	3.11	1.53	617 (42)	2.58	1.30	1,232 (35)	2.83	1.43
cooperative climate	1	5	110 (47)	3.92	1.17	429 (23)	4.00	1.00	446 (30)	4.07	1.00	985 (28)	4.02	1.02
Acceptance of Difference														
exposure to diversity	1	6	99 (42)	2.03	0.99	488 (26)	1.88	0.96	536 (36)	2.08	1.06	1,123 (32)	1.99	1.02
friends share race/ethnicity	1	4	103 (44)	2.77	1.09	410 (22)	2.70	1.12	435 (30)	2.72	1.11	948 (27)	2.72	1.11
friends share gender/gender identity	1	4	103 (44)	2.86	0.89	406 (22)	2.77	0.95	433 (29)	2.79	0.92	942 (26)	2.79	0.93
experiences of discrimination	1	6	98 (42)	1.83	1.10	492 (26)	1.55	0.86	539 (37)	1.62	0.90	1,129 (32)	1.61	0.90
sense of belonging	1	6	100 (43)	2.98	1.34	485 (26)	2.54	1.13	539 (37)	2.65	1.14	1,124 (32)	2.63	1.16
welcoming climate	1	5	110 (47)	3.91	1.20	428 (23)	4.09	1.02	446 (30)	4.10	1.01	984 (28)	4.07	1.03

suicidal ideation, 5.98% of respondents, or 203 engineering graduate students, reported having some form of suicidal ideation in over these three academic years.

Examining trends in cultural covariates under the dimension of an engineering way of thinking, I found that for *degree persistence*, the average response was a 1.79 or between strongly agree and agree; *help seeking makes you a failure* was a 2.61, or between agree and somewhat agree; *help seeking makes you lesser* was a 3.81, between somewhat agree and somewhat disagree; *keeping feelings to myself* was a 2.83 (between agree and somewhat agree); and *cooperative climate* had an average response of 4.02, corresponding to the response somewhat cooperative. When examining covariates under the dimension acceptance of difference, the average scores were as follows: *exposure to diversity* was a 1.99 (agree), *friends share race/ethnicity* was a 2.72 (between 26-50% and 51-75%), *friends share gender/gender identity* was a 2.79 (between 26-50% and 51-75%), *experiences of discrimination in the past year* was a 1.61 (between never and once in a while), *sense of belonging* was a 2.63 (between agree and somewhat agree), and *welcoming climate* was a 4.07 (corresponding to somewhat welcoming).

5.4.2 Trends Over Past Three Academic Years

The results from the t-tests are detailed in Table 5-8. Focusing on the outcomes of interest, the only statistically significant changes were found comparing 2019-20 responses to 2020-21 responses. There, *anxiety* and *depression* had statistically significant increases in their means, with *flourishing* having a statistically significant decrease in the average score. This indicates that mental health problems got worse from 2019-20 to 2020-21. Examining cultural covariates under the dimension an engineering way of thinking, the covariate *degree persistence* indicated a statistically significant decrease in score from 2018-19 to 2019-20, and then a statistically

Table 5-8. T-tests comparing outcomes of interest and cultural covariates across academic years

Measures	2018-19 v 2019-20			2019-20 v 2020-21			2018-19 v 2020-21		
	Difference in Means	t	p-value	Difference in Means	t	p-value	Difference in Means	t	p-value
Outcomes									
Anxiety	-0.331	0.957	0.339	0.610	-3.239	0.001 **	0.278	-0.783	0.434
Depression	-0.090	0.237	0.813	0.607	-2.957	0.003 **	0.517	-1.331	0.184
Flourishing	0.345	-0.587	0.557	-0.825	2.498	0.013 *	-0.481	0.797	0.426
Suicidal Ideation	0.007	-0.442	0.659	-0.003	0.367	0.714	0.004	-0.249	0.804
Cultural Covariates									
An Engineering Way of Thinking									
degree persistence	-0.213	2.768	0.006 **	0.098	1.463	0.007 **	-1.833	-2.693	0.144
help seeking makes you a failure	0.015	-0.118	0.906	-0.029	0.106	0.688	-0.013	0.402	0.916
help seeking makes you lesser	0.028	-0.205	0.838	-0.067	0.293	0.396	-0.039	0.849	0.770
keep feelings to myself	0.173	-1.146	0.254	-0.522	2.402	<0.001 ***	-0.349	6.106	0.018 *
cooperative climate	0.082	-0.671	0.504	0.065	-1.207	0.339	0.147	-0.957	0.229
Acceptance of Difference									
exposure to diversity	-0.153	1.405	0.162	0.207	-0.488	0.001 **	0.054	-3.265	0.627
friends share race/ethnicity	-0.069	0.577	0.565	0.022	0.397	0.774	-0.047	-0.287	0.692
friends share gender/gender identity	-0.093	0.939	0.349	0.021	0.734	0.744	-0.072	-0.327	0.464
experiences of discrimination	-0.276	2.337	0.021 *	0.069	1.753	0.209	-0.207	-1.258	0.082
sense of belonging	-0.442	3.077	0.003 **	0.111	2.316	0.118	-0.331	-1.565	0.022 *
welcoming climate	0.177	-1.424	0.157	0.012	-1.529	0.859	0.190	-0.178	0.128

Notes: ***p<0.001, ** p<0.01, *p<0.05; Difference in Means was calculated by following the equation: Year2 - Year1, with Year1 being the chronologically earlier academic year (e.g., for 2018-19 v 2019-20, the difference in means = 2019-20 mean - 2018-19 mean).

significant increase from 2019-20 to 2020-21. Although not statistically significant, trends comparing 2018-21 depict a decrease in degree persistence from 2018-19 to 2020-21. The covariate *keep feelings to myself* had a statistically significant decrease in average scores from both 2019-20 to 2020-21 and from 2018-19 to 2020-21. Switching to the dimension of acceptance of difference, three covariates had statistically significant differences in means. The covariate *exposure to diversity* had a statistically significant increase in means from 2019-20 to 2020-21. The covariate *experiences of discrimination* had a statistically significant decrease from 2018-19 to 2019-20, as did a *sense of belonging.* These trends were also detailed in the changes from 2018-19 to 2020-21, although only *sense of belonging* was statistically significant.

5.4.3 Relationships Between Outcomes of Interest and Covariates

The following sections present the findings examining the relationship between the students' self-reported mental health measures and the culture of engineering. First, I present the findings from the four regression analyses (one for each outcome of interest) for engineering graduate students. Findings for these models will be discussed in terms of their statistical significance, or p-value (<0.05). As previously discussed, in Models 1, 2, and 3, I will discuss the coefficients and when discussing Model 4 I will discuss the odds ratios.

I will then present the findings from regression analysis with the negative mental health outcomes of interest before detailing the findings from the positive mental health outcome of interest. Following this I will discuss the findings with regard to the demographic covariates. The end of this section will compare the findings from the regression analysis ran on engineering graduate students to the regression analysis ran on the larger, all graduate student population.

5.4.3.1 Cultural covariates and negative measures of mental health (i.e., Anxiety, Depression, and Suicidal Ideation)

Table 5-9 and Table 5-10 present the findings from the regression analysis across Models 1, 2, and 4 as these models all had negative mental health measures as the outcomes of interest (i.e., *anxiety, depression*, and *suicidal ideation*), and therefore share the same baseline comparison groups for analysis. That is, Table 5-9 and Table 5-10 present the regression results exploring the relationship between the negative mental health measures and the culture of engineering (proxied by the CEEF dimensions *an engineering way of thinking* and *acceptance of difference*). The remainder of this section will discuss the findings sequentially by model number.

Model 1: Anxiety There were several significant results from this analysis. The items *degree persistence*, *keeping feelings to myself, sense of belonging*, and *welcoming climate* all had statistically significant relationships with the *anxiety* score. As the covariate responses for *degree persistence*, *keeping to myself, sense of belonging*, and *welcoming climate* moved closer in response options to the baseline (i.e., response selected as most likely to have *anxiety*), the coefficients decreased in negative magnitude, or moved towards a higher *anxiety* score (i.e., their *anxiety* scores went down as students agreed more with the positive mental health covariates *or* disagreed more with the negative mental health covariates).

Model 2: Depression When examining the outcome of interest *depression*, the cultural covariates *degree persistence*, *keeping feelings to myself, experiences of discrimination in the past year*, and *sense of belonging* all had statistically significant relationships with the anxiety score. As the covariate responses for these proxy items moved closer in response options to the baseline (i.e., response selected as most likely to have *depression*), the coefficients decreased in negative magnitude, or moved towards a higher *depression* score (i.e., their *depression* scores

Table 5-9. Predicting relationships with negative mental health measures (Models 1, 2, & 4) and CEEF dimension, an engineering way of thinking

Theme	Proxy Item	Response Option	Model 1 (*anxiety*)			Model 2 (*depression*)			Model 4 (*suicidal ideation*)		
An Engineering Way of Thinking			Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Odds Ratio	Standard Error	p
take it											
	degree persistence	strongly agree	-2.20	0.87	0.012 *	-4.95	0.94	<0.001 ***	0.35	0.60	0.080
		agree	-1.43	0.87	0.100	-4.00	0.94	<0.001 ***	0.37	0.57	0.083
		somewhat agree	-0.29	0.85	0.732	-2.69	0.90	0.003 **	0.74	0.55	0.587
		somewhat disagree	0.10	0.94	0.918	-2.11	1.00	0.036 *	0.68	0.61	0.523
		disagree	1.61	1.00	0.109	-0.52	1.05	0.619	1.04	0.63	0.956
	help seeking makes you a failure	agree	-0.29	0.34	0.397	-0.30	0.33	0.362	0.79	0.36	0.508
		somewhat agree	-0.15	0.43	0.733	-0.17	0.46	0.707	0.91	0.36	0.783
		somewhat disagree	-0.11	0.49	0.818	-0.26	0.48	0.582	1.20	0.47	0.703
		disagree	0.34	0.57	0.549	0.22	0.72	0.755	0.88	0.55	0.810
		strongly disagree	0.11	0.75	0.879	0.22	0.74	0.767	1.23	0.68	0.762
	help seeking makes you lesser	agree	0.06	0.56	0.920	0.13	0.60	0.825	0.94	0.52	0.907
		somewhat agree	-0.38	0.56	0.495	-0.48	0.59	0.416	0.79	0.50	0.637
		somewhat disagree	-0.36	0.60	0.543	-0.67	0.65	0.306	0.61	0.54	0.364
		disagree	-0.49	0.70	0.486	-0.89	0.68	0.196	0.56	0.56	0.294
		strongly disagree	-0.44	0.80	0.588	-1.19	0.78	0.135	0.52	0.71	0.358
	keep feelings to myself	agree	-1.67	0.39	<0.001 ***	-1.92	0.44	<0.001 ***	0.45	0.29	0.008 **
		somewhat agree	-2.11	0.43	<0.001 ***	-2.42	0.45	<0.001 ***	0.55	0.30	0.051
		somewhat disagree	-2.55	0.47	<0.001 ***	-3.00	0.53	<0.001 ***	0.36	0.43	0.022 *
		disagree	-2.94	0.52	<0.001 ***	-3.37	0.64	<0.001 ***	0.37	0.52	0.058
		strongly disagree	-3.81	0.70	<0.001 ***	-4.39	0.77	<0.001 ***	0.22	0.81	0.062
cooperative climate											
	cooperative climate	somewhat uncooperative	0.42	1.15	0.717	0.53	1.12	0.638	1.35	0.91	0.744
		neither (un)cooperative	0.29	1.19	0.806	0.67	1.17	0.570	2.76	0.80	0.208
		somewhat cooperative	0.33	1.19	0.781	0.55	1.21	0.651	2.95	0.87	0.221
		very cooperative	0.34	1.37	0.805	0.50	1.27	0.696	4.92	1.03	0.129

Table 5-10. Predicting relationships with negative mental health measures (Models 1, 2, & 4) and CEEF dimension, acceptance of difference

Theme	Proxy Item	Response Option	Model 1 (*anxiety*)			Model 2 (*depression*)			Model 4 (*suicidal ideation*)		
Acceptance of Difference			Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Odds Ratio	Standard Error	p
homogeneity											
	exposure to diversity	strongly agree	0.48	1.21	0.691	0.15	1.25	0.907	3.63	1.05	0.225
		agree	0.23	1.15	0.842	-0.09	1.15	0.938	2.46	1.01	0.377
		somewhat agree	0.32	1.04	0.758	0.03	1.07	0.976	2.50	0.98	0.353
		somewhat disagree	-0.08	1.12	0.944	-0.26	1.10	0.814	1.71	1.11	0.628
		disagree	0.01	1.17	0.992	-0.47	1.17	0.690	2.77	1.14	0.373
	friends share race/ethnicity	26-50%	-0.35	0.37	0.346	-0.48	0.41	0.255	1.48	0.37	0.294
		51-75%	-0.61	0.44	0.175	-0.77	0.54	0.164	1.71	0.43	0.217
		76-100%	-0.90	0.53	0.101	-1.00	0.64	0.133	2.27	0.52	0.129
	friends share gender/gender identity	26-50%	-0.07	0.49	0.886	-0.18	0.47	0.700	0.88	0.44	0.774
		51-75%	0.32	0.56	0.570	0.06	0.70	0.928	0.75	0.51	0.580
		76-100%	0.48	0.79	0.548	0.12	0.93	0.902	0.63	0.65	0.481
conditional acceptance											
	experiences of discrimination in the past year	never	-3.22	1.79	0.075	-3.65	1.72	0.036 *	0.41	1.36	0.513
		once in a while	-2.43	1.77	0.172	-2.81	1.76	0.114	0.67	1.23	0.749
		sometimes	-1.90	1.75	0.281	-2.16	1.80	0.231	0.60	1.19	0.672
		a lot	0.15	1.94	0.937	-0.78	1.88	0.678	1.75	1.23	0.653
		most of the time	-0.79	2.08	0.705	-3.14	2.35	0.184	0.72	1.49	0.828
first impressions											
	sense of belonging	strongly agree	-4.52	0.99	<0.001 ***	-7.19	1.19	<0.001 ***	0.11	0.94	0.024 *
		agree	-3.77	0.90	<0.001 ***	-6.05	1.12	<0.001 ***	0.23	0.73	0.052
		somewhat agree	-2.80	0.80	<0.001 ***	-4.52	1.03	<0.001 ***	0.42	0.60	0.150
		somewhat disagree	-2.04	0.74	0.007 **	-3.43	0.95	<0.001 ***	0.54	0.55	0.270
		disagree	-1.38	0.88	0.122	-1.82	1.17	0.128	0.72	0.57	0.570
	welcoming climate	somewhat not welcoming	-0.75	0.88	0.398	-1.02	0.91	0.265	0.83	0.70	0.789
		neither (not) welcoming	-1.63	0.99	0.108	-1.87	1.13	0.108	0.34	0.73	0.141
		somewhat welcoming	-2.08	0.97	0.038 *	-2.21	1.19	0.072	0.20	0.74	0.038 *
		welcoming	-2.91	1.25	0.026 *	-2.80	1.41	0.055	0.11	0.97	0.030 *

went down as students agreed more with the positive mental health covariates *or* disagreed more with the negative mental health covariates).

Model 4: Odds of Suicidal Ideation Findings detailed several cultural covariates that had a statistically significant decreased odds of self-reporting suicidal ideation. Specifically, if a participant indicated that they do not *keep feelings to themselves* when depressed, feel that they have a *sense of belonging*, or experience a *welcoming* campus climate, they had a statistically significant decreased odds of self-reporting *suicidal ideation* in the past year. The same is true for the opposite, in that agreeing with *keeping feelings to myself* when depressed, not having a *sense of belonging,* and experiencing an *unwelcoming climate* had an increased odds of self-reporting *suicidal ideation* in the past year. No other cultural covariates were found to have statistically significant odds, although these trends were generally followed by the other covariates.

5.4.3.2 Cultural covariates and positive measures of mental health (i.e., Flourishing)

Table 5-11 presents the findings form the regression analysis from Model 3. As previously discussed, this analysis examined a positive mental health measure as the outcome of interest and therefore had inverted baseline comparison groups compared to the other models.

Model 3: Flourishing When taking into consideration that this model was indicative of increasing self-reported positive mental health compared to increasing mental health problems, this model seems to follow findings from the other models. In terms of the cultural covariates, *degree persistence*, *help seeking makes you a failure*, *help seeking makes you lesser, keeping feelings to myself*, and *sense of belonging* all had statistically significant relationships with the *flourishing* score. For most covariates, as the responses moved closer to the baseline option (i.e., response selected as most likely to have higher levels of *flourishing*), the coefficients decreased

Table 5-11. Predicting relationships with *flourishing* (Model 3) and CEEF dimensions, an engineering way of thinking (left) and acceptance of difference (right)

Theme	Proxy Item	Response Option	Raw Coefficient	Standard Error	p	
An Engineering Way of Thinking						
take it						
	degree persistence	agree	-2.40	0.34	<0.001	***
		somewhat agree	-4.77	0.50	<0.001	***
		somewhat disagree	-6.38	0.95	<0.001	***
		disagree	-7.78	1.15	<0.001	***
		strongly disagree	-9.31	1.55	<0.001	***
	help seeking makes you a failure	strongly agree	2.32	1.30	0.080	
		agree	2.75	1.24	0.032	*
		somewhat agree	2.63	1.15	0.026	*
		somewhat disagree	1.92	1.25	0.132	
		disagree	1.75	1.41	0.219	
	help seeking makes you lesser	strongly agree	-3.12	1.02	0.003	**
		agree	-2.27	0.79	0.006	**
		somewhat agree	-1.68	0.67	0.014	*
		somewhat disagree	-1.34	0.64	0.040	*
		disagree	-0.79	0.52	0.126	
	keep feelings to myself	strongly agree	-4.36	1.13	<0.001	***
		agree	-2.45	0.92	0.010	*
		somewhat agree	-1.82	0.81	0.027	*
		somewhat disagree	-1.22	0.75	0.108	
		disagree	-0.98	0.72	0.171	
cooperative climate						
	cooperative climate	very uncooperative	0.07	2.13	0.975	
		somewhat uncooperative	0.06	1.70	0.974	
		neither (un)cooperative	-0.65	1.35	0.635	
		somewhat cooperative	-0.11	0.80	0.890	

Theme	Proxy Item	Response Option	Raw Coefficient	Standard Error	p	
Acceptance of Difference						
homogeneity						
	exposure to diversity	agree	-0.48	0.48	0.317	
		somewhat agree	-1.52	0.77	0.057	
		somewhat disagree	-0.97	1.16	0.406	
		disagree	-2.57	1.48	0.088	
		strongly disagree	-1.49	2.03	0.468	
	friends share race/ethnicity	0-25%	-1.38	1.01	0.185	
		26-50%	-0.53	0.78	0.499	
		51-75%	-0.19	0.48	0.692	
	friends share gender/gender identity	0-25%	-0.99	1.85	0.598	
		26-50%	-0.40	1.13	0.730	
		51-75%	-0.06	0.67	0.923	
conditional acceptance						
	experiences of discrimination in the past year	once in a while	0.13	0.42	0.759	
		sometimes	0.17	0.75	0.822	
		a lot	-0.35	1.55	0.822	
		most of the time	4.03	3.08	0.198	
		almost all of the time	-2.73	2.67	0.308	
first impressions						
	sense of belonging	agree	-2.53	0.55	<0.001	***
		somewhat agree	-5.54	0.71	<0.001	***
		somewhat disagree	-7.87	0.98	<0.001	***
		disagree	-10.66	1.33	<0.001	***
		strongly disagree	-13.56	1.44	<0.001	***
	welcoming climate	not welcoming	-2.02	2.05	0.330	
		somewhat not welcoming	-1.45	1.63	0.383	
		neither (not) welcoming	-1.08	1.22	0.384	
		somewhat welcoming	-0.74	0.81	0.371	

in negative magnitude, or moved towards a higher *flourishing* score (i.e., their *flourishing* scores went up as students agreed more with the positive mental health covariates *or* disagreed more with the negative mental health covariates). The main exception is *help seeking makes you lesser*, where the trend changes as the responses move closer to the baseline option (i.e., their *flourishing* scores went down as agreed less with the negative mental health covariate); this reversed but those responses were not statistically significant.

5.4.3.3 Demographic covariates and measures of mental health (i.e., Anxiety, Depression, Flourishing, and Suicidal Ideation)

Table 5-12 details the findings across the four models with respect to the demographic covariates. The sections below detail these findings for each outcome of interest.

Model 1: Anxiety When compared to the baselines of being a first-year White male domestic student in a master's program, there were statistically significant influences in the *anxiety* score for the demographics of gender (female), international student (yes), and degree program (doctoral), with all but degree program having positive relationships.

Model 2: Depression For the outcome of interest *depression*, when compared to the baselines of being a first-year White male domestic student in a master's program, there were statistically significant influences in the *anxiety* score for the demographics of gender (female) and degree program (doctoral), with degree program having a negative relationship and gender a positive relationship.

Model 3: Flourishing There were statistically significant influences in the *flourishing* score when comparing to the baseline demographic covariate groups of being a first-year White male domestic student in a master's program. For the demographics of race/ethnicity (Asian/Asian-American) and international student (yes), there was a statistically significant

Table 5-12. Detailing findings across Models 1 - 4 by demographic covariates

		Model 1 (*anxiety*)			Model 2 (*depression*)			Model 3 (*flourishing*)			Model 4 (*suicidal ideation*)		
Demographic Category	Response Option	Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Odds Ratio	Standard Error	p
gender	Female	1.41	0.21	<0.001 ***	1.00	0.22	<0.001 ***	-0.47	0.34	0.173	1.38	0.18	0.075
	Neither Female nor Male	0.12	0.78	0.875	-0.37	0.83	0.652	0.34	1.39	0.808	3.33	0.53	0.024 *
race / ethnicity	African American/Black	-0.77	0.51	0.130	0.32	0.54	0.553	-0.20	0.84	0.816	1.37	0.48	0.514
	Asian/Asian-American	-0.17	0.27	0.525	0.15	0.30	0.608	-2.14	0.47	<0.001 ***	1.56	0.26	0.093
	Hispanic/Latino	-0.08	0.42	0.845	0.14	0.45	0.748	0.03	0.72	0.970	0.89	0.47	0.794
	Middle Eastern, Arab, or Arab American	0.54	0.41	0.184	0.59	0.45	0.189	-0.44	0.73	0.544	0.85	0.46	0.732
	Multi-Racial or Other	0.23	0.41	0.575	0.12	0.43	0.772	-0.90	0.67	0.178	0.89	0.40	0.764
year in program	Second Year	0.08	0.20	0.695	0.17	0.21	0.417	-0.15	0.35	0.661	1.27	0.20	0.236
	Third Year	-0.04	0.28	0.891	-0.21	0.30	0.484	0.08	0.50	0.877	0.83	0.30	0.530
	Fourth Year	0.40	0.31	0.199	0.36	0.33	0.281	-0.74	0.54	0.170	0.73	0.32	0.317
	Fifth Year	-0.20	0.44	0.657	0.14	0.49	0.776	0.75	0.79	0.342	0.89	0.45	0.803
	Sixth Year	-0.04	0.70	0.951	-0.42	0.76	0.582	-1.42	1.22	0.245	1.13	0.63	0.847
	Seventh(+) Year	-0.53	0.81	0.517	0.38	0.85	0.659	-1.14	1.33	0.394	0.25	1.15	0.227
international student	Yes	0.61	0.26	0.019 *	0.57	0.31	0.072	-1.00	0.48	0.042 *	0.56	0.25	0.020 *
degree program	Doctoral	-0.44	0.21	0.041 *	-0.95	0.25	<0.001 ***	1.14	0.39	0.004 **	0.93	0.20	0.729

negative relationship with the *flourishing* score. For the demographic covariate degree program (doctoral), there was a statistically significant positive relationship with the *flourishing* score.

Model 4: Odds of Suicidal Ideation There was a statistically significant change in the odds of self-reporting *suicidal ideation* in the past year when comparing response categories to the baselines of being a first-year White male domestic student in a master's program. Both demographics of gender (neither female nor male) and international student (yes) had a statistically significant increased odds in self-reporting *suicidal ideation*.

5.4.3.4 Comparing to the larger, all graduate student models

As discussed in the analysis approach section, I repeated the regression analysis completed on engineering graduate students (i.e., Models 1 through 4) with a larger sample including all graduate student populations. The following sections will compare these analyses, first focusing on the cultural covariates before discussing any differences found with respect to the demographic covariates.

Cultural Covariates Table 5-13 details the descriptive statistics on the aggregate 2018-2021 sample for the measures used in analysis (i.e., outcomes of interest and cultural covariates). I ran performed Welch's two-sided t-tests (again, using Equations 1a, 1b, and 1c) to examine whether there was a statistically significant difference in means between the engineering only graduate sample and the all graduate student sample (which included engineering students). When calculating the difference in means, I subtracted the mean of the all graduate student sample from the engineering graduate student mean. Table 5-14 details the findings from this analysis. As detailed, there were several statistically significant findings.

On average, engineering graduate students self-reported lower scores on all mental health measures, regardless of the measure (i.e., both negative measures of anxiety, depression, and suicidal ideation as well as the positive mental health measure of flourishing). Under the cultural covariates, engineering graduate students, on average, self-reported lower scores for the measures *keep feelings to myself* and *friends share gender/gender identity*, and self-reported higher scores for the measures *help seeking makes you a failure* and *cooperative climate*. These findings suggest that engineering graduate students, on average, (a) agreed more with keeping feelings to themselves when feeling depressed or sad, (b) perceived themselves to have a lower percentage of friends that shared their same gender/gender identity, (c) disagreed more with the statement that people think less of a person who has received mental health treatment, and (d) perceived their school climate to be more cooperative when compared to all students, on average.

The findings from the regression analysis for the larger, all graduate student population are detailed in Table 5-15, Table 5-16, and Table 5-17. Table 5-15 and Table 5-16 detail the findings for negative measures of mental health and the CEEF dimensions an engineering way of thinking and acceptance of difference, respectively. Table 5-17 details the findings for the positive measure of mental health and the dimensions of CEEF. Most items that had statistical significance for engineering graduate students also had statistical significance for all graduate students. The only item that did not follow the same trends in the full graduate student analyses compared to the engineering only analyses was the item *welcoming climate*. That is, under Model 1 and Model 4, *anxiety* scores went down/there was a reduced odds in reporting suicidal ideation as students agreed more with there being a *welcoming climate*. Furthermore, this item was seen to be statistically significant under the full graduate student model for *depression* and *flourishing*, but not for the engineering student model. Additionally, there were many items found to be statistically significant for the full graduate student population compared to just engineering graduate students.

Table 5-13. Descriptive statistics for outcomes of interest and cultural covariates for all graduate student sample

Measures	Range Min	Range Max	2018-2021 N (%)	Mean	Std. Dev.
Outcomes			28,230		
Anxiety	0	21	26571 (100)	6.73	5.45
Minimal	*0*	*4*	*11,187* (39.6)	-	-
Mild	*5*	*9*	*8,215* (29.1)	-	-
Moderate	*10*	*14*	*4,218* (14.9)	-	-
Severe	*15*	*21*	*2,951* (10.5)	-	-
Depression	0	27	26,632 (94)	7.52	5.75
None	*0*	*4*	*9,652* (34.2)	-	-
Mild	*5*	*9*	*8,991* (31.8)	-	-
Moderate	*10*	*14*	*4,518* (16.0)	-	-
Moderately Severe	*15*	*19*	*2,238* (7.9)	-	-
Severe	*20*	*27*	*1,233* (4.4)	-	-
Flourishing	8	56	27,270 (97)	44.64	8.43
Suicidal Ideation	0	1	26,954 (95)	0.076	0.26
Yes	*1*	*1*	*2,047* (7.3)	-	-
Cultural Covariates					
An Engineering Way of Thinking					
degree persistence	1	6	27,815 (99)	1.76	1.01
help seeking makes you a failure	1	6	10,064 (36)	2.45	1.11
help seeking makes you lesser	1	6	10,063 (36)	3.84	1.31
keep feelings to myself	1	6	10,141 (36)	2.96	1.44
cooperative climate	1	5	8,470 (30)	3.93	1.06
Acceptance of Difference					
exposure to diversity	1	6	9,093 (32)	1.99	1.05
friends share race/ethnicity	1	4	8,206 (29)	2.78	1.11
friends share gender/gender identity	1	4	8,164 (29)	2.96	0.93
experiences of discrimination	1	6	9,133 (32)	1.62	0.91
sense of belonging	1	6	9,125 (32)	2.68	1.17
welcoming climate	1	5	8,478 (30)	4.01	1.05

Table 5-14. T-test comparing engineering graduate students' mean responses to the all graduate student sample's responses

Measures	Engineering			All Graduate Students			T-Test Results		
	N	Mean	Std. Dev.	N	Mean	Std. Dev.	Difference in Means	t	p-value
Outcomes	3,564			28,230					
Anxiety	3,373	5.79	5.18	26571	6.73	5.45	-0.944	-9.905	0.000 ***
Depression	3,384	7.18	5.68	26,632	7.52	5.75	-0.341	-3.283	0.001 **
Flourishing	3,445	43.28	9.18	27,270	44.64	8.43	-1.362	-8.272	0.000 ***
Suicidal Ideation	3,397	0.06	0.24	26,954	0.076	0.26	-0.016	-3.698	0.000 ***
Cultural Covariates									
An Engineering Way of Thinking									
degree persistence	3,517	1.79	1.03	27,815	1.76	1.01	0.030	1.619	0.106
help seeking makes you a failure	1,218	2.61	1.18	10,064	2.45	1.11	0.158	4.417	0.000 ***
help seeking makes you lesser	1,221	3.81	1.32	10,063	3.84	1.31	-0.034	-0.856	0.392
keep feelings to myself	1,232	2.83	1.43	10,141	2.96	1.44	-0.130	-3.027	0.002 **
cooperative climate	985	4.02	1.02	8,470	3.93	1.06	0.090	2.608	0.009 **
Acceptance of Difference									
exposure to diversity	1,123	1.99	1.02	9,093	1.99	1.05	-0.001	-0.021	0.983
friends share race/ethnicity	948	2.72	1.11	8,206	2.78	1.11	-0.065	-1.703	0.089
friends share gender/gender identity	942	2.79	0.93	8,164	2.96	0.93	-0.169	-5.279	0.000 ***
experiences of discrimination	1,129	1.61	0.90	9,133	1.62	0.91	-0.012	-0.434	0.664
sense of belonging	1,124	2.63	1.16	9,125	2.68	1.17	-0.049	-1.341	0.180
welcoming climate	984	4.07	1.03	8,478	4.01	1.05	0.062	1.781	0.075

Notes: ***p<0.001, ** p<0.01, *p<0.05; Difference in Means was calculated by subtracting the all graduate student sample from the engineering graduate student sample.

Table 5-15. Predicting relationships with negative mental health measures (Models 1, 2, & 4) and CEEF dimension, an engineering way of thinking for the all graduate student regression analyses

Theme	Proxy Item	Response Option	Model 1 (*anxiety*)			Model 2 (*depression*)			Model 4 (*suicidal ideation*)		
An Engineering Way of Thinking			Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Odds Ratio	Standard Error	p
take it											
	degree persistence	strongly agree	-4.07	0.36	<0.001 ***	-5.53	0.36	<0.001 ***	0.39	0.183	<0.001 ***
		agree	-3.26	0.35	<0.001 ***	-4.48	0.35	<0.001 ***	0.49	0.179	<0.001 ***
		somewhat agree	-2.03	0.35	<0.001 ***	-2.83	0.36	<0.001 ***	0.75	0.178	0.106
		somewhat disagree	-1.20	0.37	0.001 **	-1.86	0.40	<0.001 ***	0.98	0.196	0.920
		disagree	-0.57	0.40	0.154	-1.08	0.41	0.009 **	0.99	0.206	0.959
	help seeking makes you a failure	agree	-0.35	0.12	0.006 *	-0.21	0.12	0.078	0.93	0.108	0.473
		somewhat agree	-0.40	0.15	0.008 *	-0.18	0.15	0.239	1.06	0.119	0.629
		somewhat disagree	-0.56	0.20	0.006 *	-0.24	0.18	0.175	1.21	0.141	0.183
		disagree	-0.53	0.27	0.057	-0.21	0.25	0.408	1.18	0.169	0.342
		strongly disagree	-0.39	0.40	0.343	0.13	0.35	0.705	1.74	0.216	0.013 *
	help seeking makes you lesser	agree	-0.36	0.23	0.126	-0.45	0.30	0.139	0.81	0.146	0.162
		somewhat agree	-0.74	0.24	0.003 **	-0.81	0.30	0.011 *	0.68	0.149	0.013 *
		somewhat disagree	-0.91	0.26	0.001 **	-1.00	0.34	0.006 **	0.66	0.153	0.008 **
		disagree	-1.14	0.29	<0.001 ***	-1.19	0.36	0.002 **	0.56	0.163	<0.001 ***
		strongly disagree	-1.27	0.32	<0.001 ***	-1.35	0.37	<0.001 ***	0.51	0.203	0.002 **
	keep feelings to myself	agree	-1.26	0.13	<0.001 ***	-1.84	0.13	<0.001 ***	0.60	0.094	<0.001 ***
		somewhat agree	-2.08	0.13	<0.001 ***	-2.87	0.13	<0.001 ***	0.48	0.108	<0.001 ***
		somewhat disagree	-2.39	0.15	<0.001 ***	-3.34	0.14	<0.001 ***	0.41	0.141	<0.001 ***
		disagree	-3.08	0.17	<0.001 ***	-4.12	0.16	<0.001 ***	0.32	0.175	<0.001 ***
		strongly disagree	-3.60	0.21	<0.001 ***	-4.77	0.20	<0.001 ***	0.20	0.309	<0.001 ***
cooperative climate											
	cooperative climate	somewhat uncooperative	0.16	0.35	0.661	0.40	0.37	0.290	1.10	0.223	0.660
		neither (un)cooperative	-0.40	0.47	0.404	-0.10	0.50	0.837	1.06	0.280	0.830
		somewhat cooperative	-0.50	0.58	0.403	-0.15	0.62	0.812	1.15	0.297	0.645
		very cooperative	-0.69	0.74	0.364	-0.36	0.77	0.646	1.20	0.366	0.629

Table 5-16. Predicting relationships with negative mental health measures (Models 1, 2, & 4) and CEEF dimension, acceptance of difference for the all graduate student regression analyses

Theme	Proxy Item	Response Option	Model 1 (*anxiety*)			Model 2 (*depression*)			Model 4 (*suicidal ideation*)		
Acceptance of Difference			Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Odds Ratio	Standard Error	p
homogeneity											
	exposure to diversity	strongly agree	1.28	0.36	<0.001 ***	1.09	0.39	0.007 **	1.54	0.247	0.086
		agree	0.87	0.33	0.009 *	0.75	0.36	0.039 *	1.35	0.238	0.216
		somewhat agree	0.64	0.33	0.056	0.66	0.36	0.068	1.28	0.246	0.321
		somewhat disagree	0.32	0.37	0.391	0.23	0.39	0.550	1.11	0.276	0.704
		disagree	0.08	0.36	0.831	0.25	0.40	0.528	1.06	0.303	0.843
	friends share race/ethnicity	26-50%	-0.18	0.14	0.202	-0.10	0.14	0.494	0.99	0.134	0.957
		51-75%	-0.35	0.17	0.044 *	-0.21	0.18	0.243	1.00	0.110	0.994
		76-100%	-0.44	0.25	0.086	-0.25	0.27	0.362	1.03	0.136	0.823
	friends share gender/gender identity	26-50%	-0.30	0.20	0.136	-0.49	0.22	0.033 *	0.87	0.139	0.328
		51-75%	-0.33	0.27	0.240	-0.74	0.29	0.016 *	0.75	0.154	0.067
		76-100%	-0.37	0.35	0.303	-0.94	0.40	0.029 *	0.68	0.187	0.043 *
conditional acceptance											
	experiences of discrimination in the past year	never	-4.04	0.51	<0.001 ***	-3.85	0.73	<0.001 ***	0.57	0.322	0.088
		once in a while	-3.24	0.49	<0.001 ***	-3.08	0.70	<0.001 ***	0.71	0.309	0.272
		sometimes	-2.53	0.51	<0.001 ***	-2.29	0.73	0.004 **	0.77	0.308	0.408
		a lot	-1.36	0.55	0.016 *	-1.34	0.75	0.084	0.96	0.311	0.908
		most of the time	-1.16	0.76	0.137	-1.09	0.93	0.252	0.99	0.350	0.975
first impressions											
	sense of belonging	strongly agree	-4.19	0.30	<0.001 ***	-5.12	0.34	<0.001 ***	0.27	0.218	<0.001 ***
		agree	-3.19	0.27	<0.001 ***	-4.12	0.30	<0.001 ***	0.38	0.176	<0.001 ***
		somewhat agree	-2.21	0.26	<0.001 ***	-2.95	0.29	<0.001 ***	0.55	0.156	<0.001 ***
		somewhat disagree	-1.49	0.27	<0.001 ***	-2.10	0.28	<0.001 ***	0.63	0.166	0.006 **
		disagree	-0.83	0.30	0.007 **	-1.18	0.31	<0.001 ***	0.79	0.162	0.156
	welcoming climate	somewhat not welcoming	-0.18	0.37	0.630	-0.41	0.32	0.210	0.86	0.206	0.475
		neither (not) welcoming	-0.48	0.42	0.258	-0.87	0.41	0.040 *	0.69	0.282	0.190
		somewhat welcoming	-0.84	0.52	0.113	-1.38	0.51	0.011 *	0.59	0.311	0.102
		welcoming	-1.15	0.64	0.085	-1.76	0.62	0.009 **	0.48	0.377	0.058

Table 5-17. Predicting relationships with *flourishing* (Model 2) and CEEF dimensions, an engineering way of thinking (left) and acceptance of difference (right) for the all graduate student regression analyses

Theme	Proxy Item	Response Option	Raw Coefficient	Standard Error	p
An Engineering Way of Thinking					
take it					
	degree persistence	agree	-1.98	0.11	<0.001 ***
		somewhat agree	-4.50	0.17	<0.001 ***
		somewhat disagree	-7.08	0.31	<0.001 ***
		disagree	-7.29	0.40	<0.001 ***
		strongly disagree	-9.77	0.57	<0.001 ***
	help seeking makes you a failure	strongly agree	2.68	0.64	<0.001 ***
		agree	2.70	0.62	<0.001 ***
		somewhat agree	2.41	0.61	<0.001 ***
		somewhat disagree	2.04	0.58	0.001 **
		disagree	1.67	0.64	0.013 *
	help seeking makes you lesser	strongly agree	-1.31	0.50	0.012 *
		agree	-0.76	0.29	0.012 *
		somewhat agree	-0.68	0.27	0.016 *
		somewhat disagree	-0.45	0.23	0.059
		disagree	-0.22	0.20	0.283
	keep feelings to myself	strongly agree	-4.69	0.31	<0.001 ***
		agree	-2.77	0.28	<0.001 ***
		somewhat agree	-1.70	0.25	<0.001 ***
		somewhat disagree	-1.32	0.27	<0.001 ***
		disagree	-0.53	0.25	0.039 *
cooperative climate					
	cooperative climate	very uncooperative	-0.13	0.89	0.886
		somewhat uncooperative	-0.52	0.70	0.463
		neither (un)cooperative	-0.26	0.46	0.575
		somewhat cooperative	-0.19	0.28	0.504

Theme	Proxy Item	Response Option	Raw Coefficient	Standard Error	p
Acceptance of Difference					
homogeneity					
	exposure to diversity	agree	-0.29	0.13	0.035 *
		somewhat agree	-0.70	0.21	0.002 **
		somewhat disagree	-0.57	0.38	0.145
		disagree	-0.94	0.45	0.041 *
		strongly disagree	-0.55	0.73	0.452
	friends share race/ethnicity	0-25%	-0.08	0.42	0.843
		26-50%	-0.01	0.31	0.987
		51-75%	0.07	0.20	0.726
	friends share gender/gender identity	0-25%	-1.27	0.47	0.012 *
		26-50%	-0.60	0.32	0.071
		51-75%	-0.24	0.20	0.231
conditional acceptance					
	experiences of discrimination in the past year	once in a while	0.17	0.14	0.228
		sometimes	0.29	0.23	0.205
		a lot	0.33	0.43	0.452
		most of the time	1.11	0.61	0.071
		almost all of the time	0.73	0.78	0.349
first impressions					
	sense of belonging	agree	-2.03	0.18	<0.001 ***
		somewhat agree	-4.17	0.23	<0.001 ***
		somewhat disagree	-6.07	0.37	<0.001 ***
		disagree	-7.65	0.38	<0.001 ***
		strongly disagree	-10.44	0.51	<0.001 ***
	welcoming climate	not welcoming	-2.51	0.80	0.004 **
		somewhat not welcoming	-2.24	0.71	0.004 **
		neither (not) welcoming	-1.58	0.48	0.003 **
		somewhat welcoming	-0.76	0.28	0.012 *

Demographic Covariates Table 5-18 details the findings across the four models (updated to the full graduate student population) with respect to the demographic covariates. Many of the trends found in the analyses with engineering graduate students were also present in the analysis with the full graduate student population with one exception. In the analysis with *anxiety*, being an international engineering graduate student correlated to an increase in students' self-reported *anxiety* score (on average), where this was not the case for the full graduate student population analysis. As with the cultural covariates, there were also demographic covariates found to be statistically significant for the full graduate student population that were not echoed in the analysis ran on engineering graduate students.

5.5 Discussion

Looking back at the research questions guiding this study, there were two goals in mind. The first goal was to determine how the mental health of engineering graduate students changed over 2018-2021. The second goal was to investigate the roles of cultural covariates on the self-reported mental health measures of *anxiety*, *depression*, *flourishing*, and *suicidal ideation* when accounting for the demographics of *gender*, *race*, *international student status*, *degree*, and *year in program*.

The descriptive statistics and t-test results presented achieved our first goal. These findings detail that mental health problems are increasing. It is important though to consider the practical implications of these increases. For example, the *anxiety* and *depression* scores are increasing by an average of 0.610 and 0.607 points, respectively (in 2019-20 vs. 2020-21). Although these may seem small, this data is supported by other researchers who have reported increased mental health problems among student populations in recent years (Healthy Minds Network & American College Health Association, 2020; NASEM, 2021). Although these point

Table 5-18. Detailing findings across Model 1 - 4 by demographic covariates for the all graduate student regression analyses

		Model 1 (*anxiety*)			Model 2 (*depression*)			Model 3 (*flourishing*)			Model 4 (*suicidal ideation*)		
Demographic Category	Response Option	Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Raw Coefficient	Standard Error	p	Odds Ratio	Standard Error	p
gender	Female	1.61	0.09	<0.001 ***	1.09	0.09	<0.001 ***	0.18	0.12	0.130	1.13	0.058	0.034 *
	Neither Female nor Male	1.67	0.23	<0.001 ***	1.98	0.24	<0.001 ***	-0.84	0.36	0.020 *	1.97	0.135	<0.001 ***
race / ethnicity	African American/Black	-1.46	0.13	<0.001 ***	-0.93	0.14	<0.001 ***	1.06	0.18	<0.001 ***	1.10	0.095	0.330
	Asian/Asian-American	-0.97	0.12	<0.001 ***	-0.54	0.12	<0.001 ***	-0.85	0.17	<0.001 ***	0.83	0.089	0.039 *
	Hispanic/Latino	-0.28	0.12	0.022 *	-0.14	0.12	0.251	0.56	0.18	0.002 **	0.77	0.102	0.011 *
	Middle Eastern, Arab, or Arab American	0.32	0.21	0.123	0.30	0.22	0.175	-0.35	0.30	0.239	0.78	0.188	0.195
	Multi-Racial or Other	0.25	0.12	0.042 *	0.47	0.13	<0.001 ***	-0.29	0.18	0.116	1.23	0.091	0.022 *
year in program	Second Year	0.14	0.07	0.059	0.11	0.07	0.113	-0.12	0.11	0.264	1.02	0.059	0.772
	Third Year	0.00	0.10	0.967	-0.10	0.10	0.319	-0.22	0.15	0.143	1.11	0.081	0.197
	Fourth Year	-0.01	0.13	0.921	-0.03	0.13	0.846	-0.41	0.19	0.031 *	1.03	0.105	0.814
	Fifth Year	-0.13	0.17	0.441	-0.07	0.17	0.698	-0.52	0.25	0.039 *	1.10	0.127	0.455
	Sixth Year	0.05	0.25	0.852	-0.04	0.25	0.871	-1.03	0.37	0.005 **	1.06	0.190	0.767
	Seventh(+) Year	-0.61	0.30	0.042 *	-0.32	0.32	0.309	0.02	0.45	0.961	1.03	0.215	0.897
international student	Yes	0.01	0.11	0.896	0.29	0.11	0.012 *	-1.47	0.15	<0.001 ***	0.78	0.089	0.005 **
degree program	Doctoral	-0.47	0.08	<0.001 ***	-0.49	0.08	<0.001 ***	0.64	0.13	<0.001 ***	0.83	0.061	0.002 **

increases may seem minimal, the growing trend depicts an average shift from a diagnosis of mild symptomology to moderate symptomatology. This could happen for two reasons. First, individuals experiencing mental health problems are having their symptoms exacerbated such that they are now reporting higher levels of these measures. Furthermore, data was collected at the onset of the coronavirus pandemic. Findings from recent work has demonstrated that mental health problems increased because of the coronavirus pandemic, in part due to students' experiencing increased difficulty in accessing mental health care and resources during the pandemic (Martinez & Nguyen, 2020; Young Minds, 2020). The second reason could be that there are more people reporting these mental health problems. Furthermore, although there has not been statistically significant difference in *suicidal ideation* between the years, ~6% of this population reporting suicidal ideation is 30% more than the average rate of Americans 18 years of age or older (Substance Abuse and Mental Health Services Administration, 2020; U.S. Department of Commerce, 2020).

The second goal was met through nested regression analyses. The covariates of *keep feelings to myself* and *sense of belonging* had statistically significant relationships with all four outcomes of interest, indicating that an endorsement of *keeping feelings to myself* or not feeling a *sense of belonging* correlated with an increase in *anxiety* and *depression*, an increased odds of reporting *suicidal ideation* in the past year, and a decrease in *flourishing*. These trends were also observed in *degree persistence* (although not statistically significant for *suicidal ideation*). Furthermore, the covariates *keeping feelings to myself* and *sense of belonging* have had a statistically significant decreases in mean scores across 2018-19 to 2020-21 (with trends supporting this as well for *degree persistence*, although not statistically significant). Other covariates also supported these trends: the covariate *help seeking makes you lesser* had a statistically significant relationship with *flourishing* scores, the covariate experiences of discrimination had a statistically significant relationship with *depression* scores, and the covariate *welcoming climate* had statistically significant relationships with *anxiety* and *depression.* Furthermore, all these relationships except for *welcoming climate* were mirrored in the larger all graduate student analyses. This is interesting given the Welch's t-test results, where engineers on average perceived their climate to be more cooperative. This suggests that although climates may be perceived by students to be more cooperative (regardless of if they are or are not), this does not mean that the climate is also welcoming.

As the measures of *keep feelings to myself, sense of belonging,* and *degree persistence* are so strongly related to the outcomes of interest (in addition to analysis finding that on average, engineering graduate students agreed more with keeping feelings to themselves when feeling depressed or sad compared to all graduate students), these findings highlight the need to further explore the role of the culture of engineering for how aspects of *an engineering way of thinking* and *acceptance of difference* may be contributing to students' feelings of isolation and desire to not discuss mental health concerns. Findings from Chapter 4 support these findings, having demonstrated ways students have felt isolated, overwhelmed and unsure, and othered within engineering and how these dimensions of CEEF contribute to these experiences.

In terms of demographic covariates being an *international*, *master's,* and/or *non-male* (either *female* or *neither female nor male*) student all had higher scores for measures of mental health problems (and conversely lower scores for positive mental health) and/or increased odds in reporting *suicidal ideation* in the past year compared to white male domestic students in a doctoral engineering program. Outside of this *Asian/Asian-American* students had significantly lower *flourishing* scores compared to White students.

Most of these findings were echoed in the larger all graduate student analyses. This validated the role of these cultural measures in being related to graduate students. At the same time, there were differences between the findings from the engineering graduate student analyses and the full graduate student analyses. Specifically, the cultural covariate of *welcoming climate* and the demographic covariate of being an *international student* both had unique trends within the analysis for engineering graduate students not repeated in analyses with the larger graduate student sample. In addition, the findings in the larger model had many statistically significant relationships between the outcomes of interest and both sets of covariates (cultural and demographic) that were not found within the engineering student analyses. These findings support that there are differences in the culture of engineering and the larger culture for graduate students within higher education.

Findings detailed how, on average, international graduate students in engineering had a statistically significant increase in their reported *anxiety* scores compared to domestic graduate students that was not found in the full graduate student model. International students are known to be less likely to report or seek help for mental health concerns (Hyun et al., 2007; Mikal et al., 2015). At the same time, international students face higher levels of acculturation stress, or stressors in assimilating to a new culture from transitioning to both a new country and norms within higher education (Bork & Mondisa, 2022; Hyun et al., 2007; Li & Stodolska, 2006; Liao & Wei, 2014; Mikal et al., 2015; Rice et al., 2012; Zhou, 2014). For example, international students confront cultural barriers that increase barriers to connect with their domestic peers and form friendships (Li & Stodolska, 2006; Mikal et al., 2015). Furthermore, there is a larger proportion of international students enrolled in science and engineering fields, with engineering graduate programs having the largest proportion of international students at over half (~57%) in

2020 (National Center for Science and Engineering Statistics, 2021; National Science Board, 2022). These trends were echoed in this data set, with 54% of engineering graduate students being international students, yet only 19% of students in the full graduate student population were international students.

This study found that graduate students within engineering uniquely experienced a correlation between their environmental climate (i.e., *welcoming climate*) and their self-reported negative mental health experiences. That is, the measure *welcoming climate* was significantly related to engineering students' responses to items on *anxiety* and *suicidal ideation*, whereas for the full graduate student analyses, this item was related to *flourishing* and *depression* scores. Considering these mental health measures (and specifically, the role of *suicidal ideation* being the extreme end of the measure depression), these findings suggest that for the broader graduate student population, a *welcoming climate* is prevalent and can help support positive mental health experiences. This is not the case for engineering students, where findings suggest that a difference in a welcoming climate is its ability to mitigate negative mental health experiences.

Many student populations are known to have increased negative experiences within engineering that impact their sense of belonging within the field. For example, a photovoice study focusing on women in science, engineering, and technology (STEM) detailed how women within these spaces often had to work to prove their competencies and leadership abilities, and how they were not recognized as authority figures by peers (Amon, 2017). Furthermore, being a woman in engineering has been connected to increased levels of distress (Cross, 2001; Fisher et al., 2019). Non-White students within engineering have shared experiences with overt and covert discrimination, including assumptions of inferiority and incompetence, that often resulted in increased stress and negative mental health experiences (Bork & Mondisa, 2022; Burt et al., 2018; McGee et al., 2019; McGee & Bentley, 2017; Torres et al., 2010). In addition, male engineering students who identify as gay have discussed how masculine centered norms specific to engineering culture contributed to them feeling unsafe and not welcome within the discipline (Hughes, 2017). Finally, findings from Chapter 4 have demonstrated how the culture of engineering is experienced differently by minoritized students within engineering and leads to feelings of isolation and being othered.

This study contributes to this work, in that a student's sense of belonging (i.e., experiencing a *welcoming climate*) is linked to their mental health experiences. This is significant as work has linked a students' sense of belonging within engineering to their intentions to persist through students' self-efficacy. Recent work has explored aspects of self-efficacy directly (i.e., as an individual's belief in their ability to act in ways they feel they need to achieve their goals; Bandura, 1993; Bandura & Baumeister, 1999; Marra et al., 2012). For example, science, engineering, and mathematics graduate students' social self-efficacy (i.e., confidence to initiate or maintain social interactions) has been connected students' self-reporting lowered depression scores and a reduced odds of suicidal ideation in the prior year (Bork & Mondisa, 2019; Wei et al., 2005). These findings highlight not only the connection between a *welcoming climate* and students' mental health experiences, but how these experiences can directly lead to them leaving engineering.

5.6 Conclusions and Future Work

Taken in a larger context, our results suggest that engineering graduate student mental health is not improving, and that the institutional and engineering program culture has a role to play in that. As researchers, we play a role in creating and maintaining that culture. We are expected to observe the principle of beneficence and secure the wellbeing of our research participants, yet there's no reason our obligation to securing wellbeing should not also extend to those in our labs, departments, and field.

However, much work remains to be done. As said in the recent NASEM report, "[T]he research on wellbeing and mental health for graduate students remains limited in comparison to undergraduate students … effective support for graduate students would benefit from increased research and program evaluation" (NASEM, 2021, p. 83). I as a research community need to further examine the role our institutions and their cultures play in influencing graduate student mental health as well as how institutions can use their power, influence, and resources to ensure all graduate students have a positive experience.

To guide this process, I suggest several areas of future work. First, researchers can expand on these findings to within the two dimensions of CEEF explored, as well as extend into the other four dimensions. For example, researchers can explore the dimension *relationship to environment* by examining how institutional and departmental characteristics might influence culture and hence, mental health outcome measures. While Posselt presents results by institution and includes perception of competitiveness in her analysis, she also calls for measures of observational competitiveness and support (Posselt, 2021). In this case, considering perceptions and rankings of institutions might provide a useful avenue for understanding larger trends in how institutions may affect students' mental health. For example, characterizing the institutions by their Carnegie Classification or research output could provide useful information about the expectations placed on students. That is, an institution whose focus is primarily on research output may lead to different mental health experiences than institutions with a less intensive research focus. Along the same line, for studies that focus on specific disciplines, discipline specific rankings or measures of the department could be used to provide additional contextual information that might influence the mental health of their students. Suggested metrics could include the known completion rate of a program, size of the program, income and benefits to students could all provide a richer context for the work environment graduate students are a part of. These measures all contribute to values, beliefs, and norms about graduate students, which are in turn enactments of the deeper cultural beliefs held and upheld within those spaces. For example, a work environment with a completion rate of doctoral students is around 50% after six-years would be expected to have differences compared to an environment with a six-year degree completion rate of 75%. From a graduate student perspective, this could mean as little as having additional potential peer mentors within their program assisting them to navigate the graduation process. Another example could be to focus on the dimension *relationship,* and specifically the student-advisor relationship. There is an abundance of literature discussing the importance of this relationship for graduate students (Amon, 2017; Bork & Mondisa, 2020; Burt et al., 2018; Posselt, 2018; Rice et al., 2009) Work exploring the advisor's role in socializing and indoctrinating their graduate students into their discipline, or the role of power dynamics in play and their effects on engineering graduate students' mental health would expand these findings. Finally, although outside the scope of this work, researchers could expand data analysis to include undergraduate data, comparing their mental health experiences and responses to CEEF in these populations.

Thinking more on this study, future researchers could also reconsider how best to handle missing data to ensure our results are generalizable but also robust. In this study, I imputed the missing data (Nissen et al., 2019; Pampaka et al., 2016). Yet, for some items with many of the students not responding (e.g., GPA in Posselt's study), such approaches might not be valid or useful. Future work should therefore focus on how best to analyze such data given the increased interest in studying student mental health. As other discipline-based education researchers have noted, I make ontological assumptions (e.g., the outcomes selected are captured by the data collected and can be seen in the aggregation of the data analyzed, etc.) and epistemological commitments (e.g., the research team positionality, results are generalizable due to the volume of data, etc.) based on the approach I take to analyze the data and answer the questions; as a result, differing commitments and assumptions might lead to different analysis approaches and questions (Ding, 2019). These factors should be further explored in future work.

In addition, future work should examine altetablernative methods of analysis and provide best practices going forward around analyzing data from this annual data set. For example, when analyzing outcome measures such as *depression*, *anxiety*, *flourishing*, etc., how best should be model them? Should I use regression approaches on the value itself as I have done here for some of the measures? Should I consider categories like minimal, mild, moderate, severe, or use a binary outcome measure (positive/negative screen)? Having a set standard for data analysis and data handling approaches would allow results from different studies to be compared easily and should be explore further by stakeholders in this work (Bork & Mondisa, 2022).

Finally, there are other considerations researchers can take into account to expand upon these results. First, considering quantitative methods, researchers can conduct a longitudinal study on engineering graduate students' mental health using stratified sampling techniques. This would allow us to see how students' mental health changes as they progress through their program, allowing possible analysis of contextual factors and concerns that engineering graduate students' face (e.g., milestone of candidacy, intentions to persist and possible attrition, etc.). Use of stratified sampling techniques could allow for more intentional participant pools for analyses and would support more intentional recruitment strategies for minoritized engineering graduate students. This in turn would allow for a richer analysis to be completed. However, researchers should also expand their methodological framing to include qualitative and mixed-methods research in this area (e.g., using mixed methods to develop targeted surveys as in similar work (Crede & Borrego, 2013). Leveraging the richness found in qualitative research can provide insight into findings that survey data is not capable of providing, both due to its intent as well as the reality of there being small sample sizes for these minority populations.

In summary, this study details how the culture of engineering programs is linked to engineering graduate students' self-reported mental health. Students' endorsement of positive program climate measures resulted in a decreased severity of mental health problems (i.e., *anxiety*, *depression*, and *suicidal* ideation) and increased scores for positive mental health (i.e., *flourishing*). Furthermore, although most of these findings are supported by the larger all graduate student analyses, findings highlighted that there is something unique about the culture of engineering that impacts students' mental health experiences differently.

5.7 Acknowledgments

I would like to thank the Healthy Minds Network for their data and resources that made this work possible (The Healthy Minds Network, 2023).

Chapter 6 Conclusions and Future Work

This dissertation sought to examine the mental health experiences of engineering graduate students. The scoping literature review detailed difficulties within existing literature and research practices that limited discussion across disciplines, and a need for research to understand the average engineering graduate students' mental health experiences (Chapter 3). The following two studies (i.e., the photovoice study in Chapter 4 and the quantitative analysis in Chapter 5) sought to address this by focusing on an overarching research question, *what are engineering graduate students' mental health experiences*?

From Chapter 5, we know that engineering graduate students' self-reported mental health problems were on the rise from 2018-2021. Chapter 4 details potential negative mental health experiences that may have contributed to this (e.g., feeling isolated and singled out, feeling overwhelmed and unsure, feeling othered, etc.). Furthermore, many of these experiences were either directly related to or exacerbated from the coronavirus pandemic and related quarantines. At the same time, Chapter 4 highlighted positive mental health experiences (e.g., having new experiences, feeling supported by peers as well as those outside of graduate school, etc.). When examining these experiences collectively, findings suggest that students' mental health experiences were related to if and/or how students sought to cope with stressors during their graduate studies. Students' positive mental health experiences were in alignment with students leveraging healthy coping mechanisms (e.g., connecting with social supports, positive self-talk, etc.), whereas negative mental health experiences were in alignment with students either not being able to utilize a preferred healthy coping mechanism and/or students using an unhealthy coping mechanism (e.g., negative self-talk, social withdrawal, etc.). As discussed in Chapter 2, research has found that engineering students are less likely to seek help compared to other disciplines (e.g., humanities or the arts; Lipson et al., 2016). Furthermore, research has established a connection between help-seeking behaviors (akin to coping mechanisms) and the culture of engineering for undergraduate engineering students (Jensen et al., 2023).

Findings exploring the relationship between the culture of engineering and engineering graduate students' mental health experiences coincide with this. The quantitative analysis study in Chapter 5 explored a subset of dimensions and themes from Godfrey and Parker's Culture of Engineering Education Framework (CEEF; Godfrey & Parker, 2010). Findings indicated that students who self-reported endorsements of *keeping feelings to myself* or *not feeling a sense of belonging* (i.e., from the theme *take it* under the dimension *An Engineering Way of Doing* and the theme *first impressions* under the dimension *Acceptance of Difference*, respectively) correlated to an increase in self-reported mental health problems (i.e., an increase in *anxiety* and *depression*, increased odds in reporting *suicidal ideation* in the past year, and a decrease in the positive mental health measure *flourishing*). Although these quantitative findings only supported a relationship between dimensions of the culture of engineering and engineering graduate students' mental health experiences, the qualitative findings in Chapter 4 found that the culture of engineering, on average had a negative impact on engineering graduate students' mental health experiences. The exceptions to this trend came from experiences where graduate students had an alignment in the cultural norm (e.g., enjoyed communicating visually, work doing aligning with post-graduation career goals, proud to be an engineer, etc.) or were having positive interactions with social supports (e.g., peers, family members, advisors, etc.). Overall, this work detailed how the culture of engineering rewards engineering graduate students who meet expectations on what engineering graduate students' backgrounds, beliefs, experiences, identities, and values engineering graduate students should be, and punishes or pushes out those who do not align with these assumptions.

This dissertation sought to understand engineering graduate students' mental health experiences. Findings from this work detailed five relevant factors: (1) academics (e.g., backgrounds, experiences, milestones, and deliverables), (2) the culture of engineering, (3) a student's background, demographics, and identities, (4) a student's current and/or previous experiences with mental health experiences, and (5) a student's relationships and social supports. As discussed throughout the findings and future implications of this work, there is a need to further explore and extend the findings from this dissertation. Therefore, the main future implication from this body of research is to treat these five factors discussed as possible inputs for a survey instrument to assess engineering graduate students' mental health. To be clear, this instrument is not intended to diagnose mental health problems or symptoms, or in any way replace the expertise and knowledge of medical and mental health professionals. Instead, the goal is for this survey instrument to be used to collect population data on engineering graduate students' mental health and related experiences.

A survey instrument can help highlight specific interactions and factors that are directly tied to engineering graduate students' mental health experiences. This can be done both using population level data as well as extend into longitudinal data that can be used to make causal inferences. Combined with current and future qualitative studies, this work may uncover engineering graduate student specific risk and protective factors. Knowing specific risk and protective factors can help inform interventions as well as policies and practices to support positive mental health experiences and remove or mitigate the impact of negative mental health experiences. This work can help shift the focus from individual mental health needs to a culture of care and interdependent positive mental health practices to support engineering graduate students' academic success.

Appendix A

Appendices for Scoping Literature Review Study (Chapter 3)

This appendix provides supplemental information for Chapter 3's Scoping Literature Review study. Table A-1 details the findings from each individual study included in this review, organized into the five major mental health categories (i.e., advisor relationship, cultural barriers faced by international students, gender and racial stereotypes, generalized findings, and social support and sense of belonging).

Table A-1. Major mental health findings

Mental health measures and main findings (Number of studies; %)	**Study cited**
Advisor relationship (9; 47%)	
Being provided opportunities and encouragement from an advisor can one see themselves staying in their field	1; Amon (2017)
Black students leaned into self-preservation coping strategies to combat feeling unwanted and unqualified to persist in their program; feelings fueled from interactions in their program with perceived belief in ability based on race; relationship perceived as threat to success with minimal opportunities to improve or build the relationship	2; Burt et al. (2018)
Dissertation writing intervention helped overcame hurdle in asking advisor for help; students shared resistance in reaching out (e.g., feeling stuck or unsure what to write, uncertainty in advisors' response, difficulty communicating barrier)	3; Carter-Veale et al. (2016)
International students with perceived functional relationships were less likely to have used counseling or report an emotional/stress related problem	7; Hyun et al. (2007)
Relationship was a source of stress and harm, with advisors being unsupportive and discouraging (e.g., being told they were incapable of doing doctoral work)	12; McGee & Bentley (2017)
Advisors vocalized expectation of no work-life balance (i.e., overwork oneself until physically/mentally drained); perceived biases in ability based on race (i.e., Asian peers viewed more capable); writer's block	13; McGee et al. (2019)
Faculty can promote positive well-being (e.g., sending an email of support, reframing struggles to reduce anxiety, validating students' struggle, confirming they belong); can build trust by downplaying gap between students and faculty; doctoral students viewed faculty as a last resort for support, fearing being viewed as incapable or lesser	15; Posselt (2018)
Although 94% of respondents did not anticipate changing advisors in next 6-12 months, 24% would if able; of 230 international students, 94 indicated poor advising (e.g., inaccessible, lack of guidance, poor feedback, excessive demands), with 66 reporting concerns with their relationship (e.g., impersonal, unsupportive, disrespectful, abusive), 12 reporting a mismatch in research interests, and 21 reporting a lack of financial support	16; Rice et al. (2009)
International students' misalignment research interests and mismatched expectations in advisor support & guidance lead to dissatisfaction	19; Zhou (2014)
Cultural barriers faced by international students (6; 32%)	

	Although similar rates of self-reported emotional/stress related problems (~45%), international students more likely to report financial problems, less likely report relationship problems, & less likely to know about or use mental health resources.	7; Hyun et al. (2007)
	Chinese international students perceived leisure activities as opportunities to relax, learn, & cope with pressure from their academic studies; leisure was often solitary or intended to further work-related goals due to temporary nature of U.S. student status; English culture & language limited social interactions and meaningful relationship building	8; Li & Stodolska (2006)
	Chinese international students proposed to face acculturation stress; found reported higher levels of stress associated with lower reported well-being; basing self-worth on academic competence resulted in negative well-being when experiencing stress, suggesting self-blame; having higher levels of family recognition through achievement (importance of academic excellence to bring honor to family) had higher reported levels of well-being	9; Liao & Wei (2014)
	Chinese students less likely to seek help for mental health concerns; turn to more culturally appropriate means for social-emotional support (i.e., friends or family) or hiding problems out of fear of worrying or disappointing them	14; Mikal et al. (2015)
	Over a third of participants met cutoffs for clinically significant psychological distress; Chinese students reported significantly higher scores of acculturative stress (measured by societal, attitudinal, familial, & environmental factors) compared to Asian Indian students (thought due to Great Britain's colonization of home country lowering assimilation stress to western culture); higher levels of self-critical perfectionism linked to higher levels of depression; self-criticism and acculturative stress compounded on one another	17; Rice et al. (2012)
	Unmet expectations (i.e., misalignment research interests, advisor support & guidance, assumptions of graduate work, lack of social support) alongside a lack of mental and academic preparation lead to increased levels of dissatisfaction; students motivated to persist due to interest in research, degree's high utility value, and fear/shame of quitting (e.g., high social cost, filial piety)	19; Zhou (2014)
Gender and racial stereotypes (6; 32%)		
	Gender stereotyping limited females' professional development opportunities; experienced lowered levels of respect in leadership roles; motivations to work (i.e., desire for collaboration, social impact, self-development) challenged by barriers faced (i.e., lack of authority, the need for vigilance, gender stereotypes); needed buffers needed to cope (i.e., accomplishments, work-life balance), with social supports empowering resiliency	1; Amon (2017)
	Black male engineering students experience discrimination from both gender and racially biased stereotyping from non-Black peers and faculty (i.e., belittling comments, lowered expectations/belief in abilities) fueled feelings of alienation, being unwanted, devalued, and unqualified; used self-preservation coping strategies to persist in toxic environments, often at cost of their own health	2; Burt et al. (2018)
	Black female engineering students experience structural racism and sexism, (i.e., sexual harassment, abuse, hostile racial climate) contributing to racial battle fatigue, chronic stress, & feeling isolated; felt need to prove themselves and required resiliency to persist	12; McGee & Bentley (2017)
	Black doctoral students prioritized academic & career success over mental/physical well-being; pro-active coping mechanisms took psychological, emotional, & physical toll (e.g., "push through" mentality); need to overcompensate work to combat gender and racial stereotypes; needed additional energy to survive day-to-day interactions, resulting in increased stress, role strain, performance anxiety, & doubt in academic abilities	13; McGee et al. (2019)
	Having faculty of the same race and/or gender helped students come forward with experiences of sexual harassment and racial discrimination.	15; Posselt (2018)
	African American students' felt isolated & like second-class citizens; experienced racial profiling (i.e., police assuming not a student); assumed intellectually inferior; added strain to cope negatively affecting mental health	18; Torres et al. (2010)
Generalized findings (4; 21%)		
	Comparing differences in academic performance; no gender differences in academic ability or perceptions of academic climate; women self-evaluated themselves to have lower levels of intelligence and reported significantly more stress longitudinally.	4; Cross (2001)
	Being a woman or feeling insignificant in STEM settings predicted increased levels of distress; perceiving success relative to peers & positive perceptions of performance standards predicted increased well-being	6; Fisher et al. (2019)
	Nation-wide survey; engineering students reported lowest help-seeking behaviors (master's 20.2%, doctoral 27.7%); 30.6% master's & 26.2% doctoral students met criteria for any self-reported mental health problem (e.g., depression, anxiety, suicidal ideation)	10; Lipson et al. (2016)
	high performing students had high reported satisfaction with jobs, career trajectory & perceived success, and overall life satisfaction	11; Lubinski et al. (2006)

Social support and sense of belonging (11; 58%)		
	Social supports provided coping mechanisms and empowered resiliency for women graduate students and postdocs in STEM; lack of woman leader role models	1; Amon (2017)
	Black male students felt unwanted in their program/department; felt isolated from others in community (e.g., peers, advisor)	2; Burt et al. (2018)
	Intervention targeting doctoral students' thesis completion & graduation; provided community, social support, & coping assistance; combatted feelings of isolation, writing paralysis, lack of directions or significant progress; helped with organization and setting measurable goals; incentivized to complete degrees on schedule	3; Carter-Veale et al. (2016)
	virtual discussion board supporting minoritized students in Bridge to Doctorate program; provided space to talk about concerns (e.g., benefits of a PhD, academia vs. industry, PWIs vs. HBCU, survival skills, fears, time management, research performance); fostered support, comradery, & a sense of belonging	5; Delaine & Fontecchio (2009)
	feeling accepted predicted increased well-being with a positive perception of departmental expectations lowering feelings of insignificance	6; Fisher et al. (2019)
	Chinese international students with higher recognition of their achievement from family had higher levels of well-being	9; Liao & Wei (2014)
	Minorized students did not feel like they belonged; lack of peers and individuals to look-up to (i.e., lack of faculty of color);	12; McGee & Bentley (2017)
	Lack of Black faculty translated to minimal supports to turn to; did not feel belonged in engineering	13; McGee et al. (2019)
	Chinese students turn to culturally appropriate means for social-emotional support (i.e., friends or family); online environment conducive for help-seeking with physical concerns (e.g., finding Chinese roommates, talking with other Chinese students in the U.S.)	14; Mikal et al. (2015)
	Students more likely to turn to peers, lab mates, and postdocs for support compared to faculty for fear of compromising their standing or being viewed as uncapable	15; Posselt (2018)
	African American students' felt isolated & like second-class citizens; felt did not belong and perceived by others as quota fillers	18; Torres et al. (2010)

This sections that follow detail the search strategies used in the scoping literature searches on March 12, 2019, and August 6, 2019, across five databases: PubMed, EBSCO: PsycINFO, EBSCO: CINAHL, ProQuest: ERIC, and Scopus. The logic conducted is (1) AND (2) AND (3) AND (4), with (1) being related to mental health in the first paragraph, (2) being related to engineering as a discipline in the second paragraph, (3) being graduate education in the third paragraph, and (4) being related to students in the fourth paragraph. Some databases had restrictions on language and publication type, which are noted at the end of each search strategy. Scopus has a different search strategy as this logic is presented twice, once to search article titles and once to search the article keywords.

PubMed

("Adaptaion, Psychological"[Mesh] OR "Behavioral Symptoms"[Mesh] OR "Counseling"[Mesh] OR "Emotions"[Mesh] OR "Mental Disorders"[Mesh] OR "Mental Health"[Mesh] OR

"Occupational Stress"[Mesh] OR "Work-Life Balance"[Mesh]) OR anxieties[tiab] OR anxiety[tiab] OR anxious[tiab] OR coping[tiab] OR counseling[tiab] OR depressed[tiab] OR depression[tiab] OR depressions[tiab] OR "depressive disorder"[tiab] OR emotional[tiab] OR emotion[tiab] OR "major depression"[tiab] OR "mental disorders"[tiab] OR "mental fatigue"[tiab] OR "mental health"[tiab] OR "panic disorder"[tiab] OR "post-traumatic stress"[tiab] OR "posttraumatic stress"[tiab] OR self-destructive[tiab] OR "self hurt"[tiab] OR "self harm"[tiab] OR self-harm[tiab] OR self-injurious[tiab] OR self-injury[tiab] OR stress[tiab] OR "stress disorder"[tiab] OR stressors[tiab] OR suicidal[tiab] OR suicide[tiab] OR trauma[tiab] OR traumatic[tiab] OR "well being"[tiab] OR well-being[tiab] OR wellbeing[tiab] OR wellness[tiab] OR "work-life balance"[tiab]

AND

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AND

("Education, Graduate"[Mesh] OR “graduate education”[tiab] OR “graduate assistant”[tiab] OR “graduate assistants”[tiab] OR “higher education”[tiab] OR doctoral[tiab] OR doctorate[tiab] OR masters[tiab] OR master’s[tiab] OR phd[tiab] OR Ph.D.[tiab] OR graduate[tiab] OR graduates[tiab] OR dissertation[tiab] OR “higher education”[tiab])

AND

("Students"[Mesh] OR student[tiab] OR students[tiab] OR candidate[tiab] OR candidates[tiab])

EBSCO: PsycInfo

DE "Affective Disorders" OR DE Anxiety OR DE "Anxiety Disorders" OR DE "anxiety management" OR DE "Counseling" OR DE "Coping Behavior" OR DE "Emotional States" OR DE "Life Satisfaction" OR DE "Major Depression" OR DE "Mental Health" OR DE "occupational stress" OR DE "post-traumatic stress" OR DE "posttraumatic stress disorder" OR DE "self-destructive behavior" OR DE "Self-Injurious Behavior" OR DE Stress OR DE "stress and trauma related disorders" OR DE "stress and coping measures" OR DE "Stress Management" OR DE "stress reactions" OR DE suicide OR DE trauma OR DE "well being" OR AB(anxieties OR anxiety OR anxious OR coping OR counseling OR depressed OR depression OR depressions OR "depressive disorder" OR emotion OR emotional OR "major depression" OR "mental disorders" OR "mental fatigue" OR "mental health" OR "panic disorder" OR "post-traumatic stress" OR "posttraumatic stress" OR self-destructive OR "self hurt" OR "self harm" OR self-harm OR self-injurious OR self-injury OR stress OR "stress disorder" OR stressors OR suicidal OR suicide OR trauma OR traumatic OR "well being" OR well-being OR wellbeing OR wellness OR "work-life balance") OR TI(anxieties OR anxiety OR anxious OR coping OR counseling OR depressed OR depression OR depressions OR "depressive disorder" OR emotion OR emotional OR "major depression" OR "mental disorders" OR "mental fatigue" OR "mental health" OR "panic disorder" OR "post-traumatic stress" OR "posttraumatic stress" OR self-destructive OR "self hurt" OR "self harm" OR self-harm OR self-injurious OR self-injury OR stress OR "stress disorder" OR stressors OR suicidal OR suicide OR trauma OR traumatic OR "well being" OR well-being OR wellbeing OR wellness OR "work-life balance")

AND

((DE “science education” OR DE “STEM” OR DE “mathematics education” OR DE “engineering” OR DE “engineers” OR DE “technology” OR DE “scientists” OR DE “mathematics” OR DE “mathematicians” OR DE “biology” OR DE “agriculture” OR DE “computer science” OR DE “information science” OR DE “astronomy” OR DE “chemistry” OR DE “physics” OR DE “psychology” OR DE “social sciences” OR DE “economics” OR DE “sociology”) OR AB("Science Education" OR "engineering education" OR "mathematics education" OR "technology education" OR "STEM education" OR "natural sciences education" OR STEM OR science OR sciences OR engineering OR engineer OR engineers OR “natural science” OR biological OR biology OR agriculture OR agricultural OR “earth science” OR geology OR geoscience OR atmospheric OR “ocean science” OR oceanography OR math OR maths OR mathematics OR “computer science” OR “information science” OR “physical science” OR astronomy OR chemical OR chemistry OR physics OR psychology OR “social science” OR “social sciences” OR economics OR “political science” OR sociology OR engineering OR technology) OR TI("Science Education" OR "engineering education" OR "mathematics education" OR "technology education" OR "STEM education" OR "natural sciences education" OR STEM OR science OR sciences OR engineering OR engineer OR engineers OR “natural science” OR biological OR biology OR agriculture OR agricultural OR “earth science” OR geology OR geoscience OR atmospheric OR “ocean science” OR oceanography OR math OR maths OR mathematics OR “computer science” OR “information science” OR “physical science” OR astronomy OR chemical OR chemistry OR physics OR psychology OR “social science” OR “social sciences” OR economics OR “political science” OR sociology OR engineering OR technology))

AND

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AND

(DE “students” OR DE “graduate students” OR DE “postgraduate students”) OR TI(student OR students OR candidates OR candidate) OR AB(student OR students OR candidates OR candidate)

AND

Language = English

Source type = academic journals

EBSCO: CINAHL

(MH "Adjustment Disorders+") OR (MH "Affective Disorders+") OR (MH "Affective Symptoms+") OR (MH "Agitation") OR (MH "Anxiety Disorders+") OR (MH "Coping+") OR (MH "Counseling+") OR (MH "Emotions+") OR (MH "Mental Fatigue+") OR (MH "Mental Status") OR (MH "Mental Health") OR (MH "Stress, Occupational+") OR (MH "Psychological Trauma+") OR (MH "psychological well-being") OR (MH "Self-Injurious Behavior") OR (MH "Stress+") OR (MH "Stress Management") OR (MH "Suicide+") OR (MH "Trauma+") OR (MH "work-life balance") OR AB(anxieties OR anxiety OR anxious OR coping OR counseling OR depressed OR depression OR depressions OR "depressive disorder" OR emotion OR emotional OR "major depression" OR "mental disorders" OR "mental fatigue" OR "mental health" OR "panic disorder" OR "post-traumatic stress" OR "posttraumatic stress" OR self-destructive OR "self hurt" OR "self harm" OR self-harm OR self-injurious OR self-injury OR stress OR "stress disorder" OR stressors OR suicidal OR suicide OR trauma OR traumatic OR "well being" OR well-being OR wellbeing OR wellness OR "work-life balance") OR TI(anxieties OR anxiety OR anxious OR coping OR counseling OR depressed OR depression OR depressions OR "depressive disorder" OR emotion OR emotional OR "major depression" OR "mental disorders" OR "mental fatigue" OR "mental health" OR "panic disorder" OR "post-traumatic stress" OR "posttraumatic stress" OR self-destructive OR "self hurt" OR "self harm" OR self-harm OR self-injurious OR self-injury OR stress OR "stress disorder" OR stressors OR suicidal OR suicide OR trauma OR traumatic OR "well being" OR well-being OR wellbeing OR wellness OR "work-life balance")

AND

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AND

(MH "Education, Graduate") OR (MH "Education, Doctoral+") OR (MH "Education, Masters+") OR TI(“graduate education” OR “graduate assistant” OR “graduate assistants” OR “higher education” OR doctoral OR doctorate OR masters OR master’s OR phd OR Ph.D. OR graduate OR graduates OR dissertation OR “higher education”) OR AB(“graduate education” OR “graduate assistant” OR “graduate assistants” OR “higher education” OR doctoral Or doctorate OR masters OR master’s OR phd OR Ph.D. OR graduate OR graduates OR dissertation OR “higher education”)

AND

(MH "Students, College") OR (MH "Students, Graduate") OR AB(student OR students OR candidate OR candidates) OR TI(student OR students OR candidate OR candidates))

ProQuest: ERIC

MAINSUBJECT.EXACT("Coping") OR MAINSUBJECT.EXACT("Depression (Psychology)") OR MAINSUBJECT.EXACT("Anxiety") OR MAINSUBJECT.EXACT("Anxiety Disorders") OR MAINSUBJECT.EXACT("Counseling") OR MAINSUBJECT.EXACT("Life Satisfaction") OR MAINSUBJECT.EXACT("Mental Health") OR MAINSUBJECT.EXACT("Posttraumatic Stress Disorder") OR MAINSUBJECT.EXACT("Self Destructive Behavior") OR MAINSUBJECT.EXACT("Stress Management") OR MAINSUBJECT.EXACT("Suicide") OR MAINSUBJECT.EXACT("Trauma") OR MAINSUBJECT.EXACT("Well Being") OR ti(anxieties OR anxiety OR anxious OR coping OR counseling OR depressed OR depression OR depressions OR "depressive disorder" OR emotion OR emotional OR "major depression" OR "mental disorders" OR "mental fatigue" OR "mental health" OR "panic disorder" OR "post-traumatic stress" OR "posttraumatic stress" OR self-destructive OR "self hurt" OR "self harm" OR self-harm OR self-injurious OR self-injury OR stress OR "stress disorder" OR stressors OR suicidal OR suicide OR trauma OR traumatic OR "well being" OR well-being OR wellbeing OR wellness OR "work-life balance")

AND

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AND

(MAINSUBJECT.EXACT.EXPLODE(“Graduate Study”) OR MAINSUBJECT.EXACT.EXPLODE(“Higher Education”) OR MAINSUBJECT.EXACT.EXPLODE(“Graduate Students”)) OR (ti(“graduate education” OR “graduate assistant” OR “graduate assistants” OR “higher education” OR doctoral Or doctorate OR masters OR master’s OR phd OR Ph.D. OR graduate OR graduates OR dissertation OR “higher education”) OR ab(“graduate education” OR “graduate assistant” OR “graduate assistants” OR “higher education” OR doctoral OR doctorate OR masters OR master’s OR phd OR Ph.D. OR graduate OR graduates OR dissertation OR “higher education”))

AND

ab(student OR students OR candidate OR candidates) OR ti(student OR students OR candidate OR candidates)

Scopus

TITLE((anxieties OR anxiety OR anxious OR {anxiety disorder} OR coping OR counseling OR depressed OR depression OR depressions OR {depressive disorder} OR emotion OR emotional OR {life satisfaction} OR {major depression} OR {mental disorders} OR {mental fatigue} OR {mental health} OR {panic disorder} OR {post-traumatic stress} OR {posttraumatic stress} OR self-destructive OR {self hurt} OR {self harm} OR self-harm OR self-injurious OR self-injury OR stress OR {stress disorder} OR stressors OR suicidal OR suicide OR trauma OR traumatic OR {well being} OR well-being OR wellbeing OR wellness OR {work-life balance}) AND ({Science education} OR {Engineering education} OR {Mathematics education} OR

{Technology education} OR {Natural Science Disciplines} OR {natural science education} OR STEM OR science OR sciences OR engineering OR engineer OR engineers OR {natural science} OR biological OR biology OR agriculture OR agricultural OR {earth science} OR geology OR geoscience OR atmospheric OR {ocean science} OR oceanography OR math OR maths OR mathematics OR {computer science} OR {information science} OR {physical science} OR astronomy OR chemical OR chemistry OR physics OR psychology OR {social science} OR {social sciences} OR economics OR {political science} OR sociology OR engineering OR technology)AND ({graduate education} OR {graduate assistant} OR {graduate assistants} OR {higher education} OR doctoral OR doctorate OR masters OR master's OR phd OR Ph.D. OR graduate OR graduates OR dissertation OR {higher education}) AND (student OR students OR candidate OR candidates))

OR

KEY((anxieties OR anxiety OR anxious OR {anxiety disorder} OR coping OR counseling OR depressed OR depression OR depressions OR {depressive disorder} OR emotion OR emotional OR {life satisfaction} OR {major depression} OR {mental disorders} OR {mental fatigue} OR {mental health} OR {panic disorder} OR {post-traumatic stress} OR {posttraumatic stress} OR self-destructive OR {self hurt} OR {self harm} OR self-harm OR self-injurious OR self-injury OR stress OR {stress disorder} OR stressors OR suicidal OR suicide OR trauma OR traumatic OR {well being} OR well-being OR wellbeing OR wellness OR {work-life balance}) AND ({Science education} OR {Engineering education} OR {Mathematics education} OR {Technology education} OR {Natural Science Disciplines} OR {natural science education} OR STEM OR science OR sciences OR engineering OR engineer OR engineers OR {natural science} OR biological OR biology OR agriculture OR agricultural OR {earth science} OR geology OR geoscience OR atmospheric OR {ocean science} OR oceanography OR math OR maths OR mathematics OR {computer science} OR {information science} OR {physical science} OR astronomy OR chemical OR chemistry OR physics OR psychology OR {social science} OR {social sciences} OR economics OR {political science} OR sociology OR engineering OR technology)AND ({graduate education} OR {graduate assistant} OR {graduate assistants} OR {higher education} OR doctoral OR doctorate OR masters OR master's OR phd OR Ph.D. OR graduate OR graduates OR dissertation OR {higher education}) AND (student OR students OR candidate OR candidates)) AND (LIMIT-TO (LANGUAGE, "English"))

Appendix B

Appendices for Photovoice Study Data Collection (Chapter 4)

This section includes the detailed information on data collection methods use to collect the data used in Chapter 4. This appendix overviews the mental health measures included in the pre-screening survey (anxiety, depression, and flourishing), the individual interview protocol, and the final focus group interview codebook.

Depression was measured using the Raw Patient Health Questionnaire score (0-27) from the Patient Health Questionnaire (PHQ; Kroenke et al., 2001; Pfizer Inc., 1999). This score can be grouped based on depressive symptom severity: 0-4 minimal depression, 5-9 mild depression, 10-14 moderate depression, 15-19 moderately severe depression, and 20-27 severe depression (Pfizer Inc., 1999). All items from the PHQ-9 questionnaire were included except for the ninth and last question, phrased "Thoughts that you would be better off dead, or of hurting yourself." This is due to the high level of depression believed to be needed to endorse this item as it relates to suicidal thoughts and ideation. Participants were still scored using the recommended categories despite this question being removed. Anxiety was measured using self-reported responses to the Beck Anxiety Inventory (Beck et al., 1998; Great Plains Health: Behavioral Health, 2021). This scale was elected as it leans into physiological experiences as diagnostic items for anxiety. Flourishing was assessed using the Psychological Well-Being scale given the intent to assess measure positive mental health (Diener et al., 2009). Unlike the previous instruments, this scale does not have categories; simply, the higher the reported composite number, the higher demonstrated positive mental health. Perceptions of academic challenges were assessed using a multi-option response question: *"Which of the following challenges would most likely prevent you from finishing your degree? Select all that apply."* The survey was modified from the Healthy Minds Network 2020-21 survey (The Healthy Minds Network (HMN), 2021). An additional option was added, specifically, "COVID-19 related delays or changes to degree progress." Last, work-life balance was measured using responses to an open-ended question: *"How would you describe your work life balance? Please be as descriptive as able."*

	Not at all	Mildly, but it didn't bother me much	Moderately – it wasn't pleasant at times	Severely – it bothered me a lot
Numbness or tingling	0	1	2	3
Feeling hot	0	1	2	3
Wobbliness in legs	0	1	2	3
Unable to relax	0	1	2	3
Fear of worst happening	0	1	2	3
Dizzy or lightheaded	0	1	2	3
Heart pounding / racing	0	1	2	3
Unsteady	0	1	2	3
Terrified or afraid	0	1	2	3
Nervous	0	1	2	3
Feeling of choking	0	1	2	3
Hands trembling	0	1	2	3
Shaky / unsteady	0	1	2	3
Fear of losing control	0	1	2	3
Difficulty in breathing	0	1	2	3
Fear of dying	0	1	2	3
Scared	0	1	2	3
Indigestion	0	1	2	3
Faint / lightheaded	0	1	2	3
Face flushed	0	1	2	3
Hot / cold sweats	0	1	2	3

Figure B-1. Screenshot of full Beck Anxiety Inventory from (Great Plains Health: Behavioral Health, 2021), generated from (Beck et al., 1998).

Over the *last 2 weeks*, how often have you been bothered by any of the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

(For office coding: Total Score ________ = ________ + ________ + ________)

If you checked off *any* problems, how *difficult* have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
☐	☐	☐	☐

Figure B-2. Screenshot of full PHQ-9 from (Kroenke et al., 2001, pp. 613).

Below are 8 statements with which you may agree or disagree. Using the 1–7 scale below, indicate your agreement with each item by indicating that response for each statement.

7 Strongly agree
6 Agree
5 Slightly agree
4 Mixed or neither agree nor disagree
3 Slightly disagree
2 Disagree
1 Strongly disagree

I lead a purposeful and meaningful life.
My social relationships are supportive and rewarding.
I am engaged and interested in my daily activities
I actively contribute to the happiness and well-being of others
I am competent and capable in the activities that are important to me
I am a good person and live a good life
I am optimistic about my future
People respect me

Scoring: Add the responses, varying from 1 to 7, for all eight items. The possible range of scores is from 8 (lowest possible) to 56 (highest PWB possible). A high score represents a person with many psychological resources and strengths.

Figure B-3. Screenshot of full Psychological Well-Being Scale (PWB) from (Diener et al., 2009).

Table B-1. Pre-screening survey questions on background and demographics

Name	Description	Response Categories
Background		
Discipline	What engineering discipline do you most closely relate to?	National Science Foundation reported categories [52]
Degree Program	What degree program are you currently enrolled in?	Master's Only Doctoral Only Joint Bachelors/Master's Program Joint Master's/Doctoral Program
Length in Program	What term did you begin your academic program?	[open response]
Academic Milestones	What, if any, academic milestones are you working toward completing this semester?	Respond with [Yes, No, or N/A] for each: Degree Coursework, Research Publication, Research Presentation, Qualifying Exam, Candidacy Advancement. Dissertation Proposal, Dissertation Writing, Dissertation Defense, Graduation, Master's Degree, Graduation, Doctoral Degree
Demographics		
Age	What is your age?	[open response]
Gender	What is your gender?	Female, Male, I prefer to identify as (please specify) [open response]
Relationship Status	How would you characterize your current relationship status?	( ) Single ( ) In a relationship ( ) Married, in a domestic partnership, or engaged ( ) Divorced or separated ( ) Widowed ( ) Other (please specify)
Living Arrangement	How would you describe your current living arrangement?	[open response]
Race/Ethnicity	What is your racial and/or ethnic identification? Please select all that apply	American Indian or Alaska Native, Asian, or Asian American, Black, or African American, Hispanic, or Latino, Multiracial/Multicultural, please specify [open response], Native Hawaiian or Pacific Islander, White/Non-Hispanic, another racial and/or ethnic identification, please specify [open response]
International Student Status	Are you an international student?	Yes or No
Children/Dependents	Are you currently responsible for any children or other dependents living in your household?	Yes or No
Parents/Caregivers' Education Levels	What is the highest level of education completed by your primary/secondary parent, guardian, or caregiver?	Eight grade or lower, between 9th or 12th grade (but no high school degree, high school degree, some college (but no college degree), Associate's degree, Bachelor's degree, Master's degree, Doctoral degree, Don't know

Table B-2. Pre-screening survey questions on academic performance

Name	Description	Response Categories
Potential Impacts	In the past year, how has the following affected your academic performance? (Select all that apply): - Anxiety / stress - Depression / Sadness / Other Mental Health Concerns - Eating / body image concern - Attention disorder or learning disability (e.g., attention deficit disorder, attention deficit hyperactivity disorder, learning disability) - Alcohol / substance use - Physical health concerns (not COVID-19 related) - Physical health concerns (COVID-19 related)	1=I did not experience this. 2=I experienced this but it did not affect my academic performance. 3=I received a lower grade on one or more exams or projects. 4=I received a lower grade in one or more courses. 5=I received an incomplete or dropped one or more courses. 6=I had a significant disruption in research, practicum, thesis, or dissertation work. 7=I had a significant disruption for my academic duties not related to my research.
Academic Persistence	How much do you agree with the following statements? - I am confident that I will be able to finish my degree no matter what challenges I may face. - I see myself as a part of the community in my specific program/department. - I am satisfied with my overall academic experience.	(1) Strongly Agree (2) Agree (3) Somewhat Agree (4) Somewhat disagree (5) Disagree (6) Strongly Disagree [Not Applicable]
Barriers to Completion	Which of the following challenges would most likely prevent you from finishing your degree? Select all that apply. 1=Financial challenges 2=Mental or emotional health problems 3=Other health problems (not directly related to mental or emotional health) 4=Family obligations 5=Family or relationship difficulties 6=Academic challenges (struggling to pass classes) 7=Visa or other challenges related to being a non-U.S. citizen 8=Lack of motivation or desire 9=Work or professional commitments 10=Career opportunities 11=COVID-19 related delays or changes to degree progress 12=Other challenge(s) (please specify)	(1) Strongly Agree (2) Agree (3) Somewhat Agree (4) Somewhat disagree (5) Disagree (6) Strongly Disagree [Not Applicable]

Table B-3. Pre-screening survey questions on mental health measures

Name	Description	Composite Response Categories
Patient Health Questionnaire (PHQ-9)	self-reported measure for severity of depression; 9 items (8 in this study)	0-4: minimal depression 5-9: mild depression 10-14: moderate depression 15-19: moderately severe depression 20-27: severe depression
Beck Anxiety Inventory (BAI)	self-report measure of anxiety; 21 items	0-21: low anxiety 22-35: moderate anxiety 36(+): potentially concerning levels of anxiety
Psychological Well-Being (PWB; Flourishing)	self-reported views on areas including relationships, self-esteem, purpose/meaning, and optimism; 8 items	Scores range from 8 (lowest) to 56 (highest); A higher score indicates a person with many psychological resources and strengths
Academic Challenges	self-reported challenges preventing participants from completing their degree; 12 items	N/A
Work-Life Balance	open-text response question: *"How would you describe your work life balance? Please be as descriptive as able."*	N/A

Table B-4. Semi-structured interview protocol.

Background/Warm Up
What academic program are you in?
What did you think grad school would be like?
Can you share your process on selecting *[current program]* at *[school]*?
Probing Images & Captions
What did you think the image solicitation prompt meant by "impactful emotional experiences?"
Can you walk me through your thought process when selecting experiences and images to include?
What range of emotional experiences were you trying to include?
Were there other impactful experiences that may not fall on either extreme you didn't include or talk about but you think would be important to share?
Mental Health & Engineering Culture
How would you define mental health?
How would you describe the culture of engineering?
How would you describe the culture surrounding mental health in engineering?
What are characteristics you associate with engineers who care about mental health?
Do you think the value of mental health changes as you move from an individual level to a department, college, or even the professional level?
What do you think are barriers to creating change around mental health in engineering?
If I had asked you to submit images that best describe what it means to be an engineer, what images would you have included?
What images from those you submitted would you include or exclude?
Cool Down
To what degree were your expectations for graduate school realized?
What advice would you give to yourself before you started grad school?
What are you planning to do after obtaining your degree?
End / "Sign Off"
Is there anything you wish I would have asked, or would like to add?
Is there anything you would like to ask me?

Table B-5. Exit survey for member checking

Question	Sub-Question(s)	Possible Responses
Please indicate how much you agree with the following statements about the study overall:	a. I understood what was expected of me to participate in this study. b. I was given time and space to ask questions as needed. c. Compensation for this study was appropriate for the level of engagement. d. I was able to engage in this study the way I wanted to. e. The implications for this work were communicated, including how these findings will be used for promoting positive experiences for engineering graduate students. f. I would have preferred two focus groups to provide more time to discuss images and explore the emerging themes. g. I would have preferred an in person focus group in order to interact with physical images/printouts and other participants. h. Knowing what I know now, I would participate again.	(1) Strongly Agree (2) Agree (3) Somewhat Agree (4) Somewhat disagree (5) Disagree (6) Strongly Disagree [Not Applicable]
Please indicate how much you agree with the following statements regarding the focus group and common themes:	a. I feel that many of my emotional experiences were NOT represented in the final groupings. b. I feel that the group touched on meaningful emotional experiences of engineering graduate students at the University of Michigan. c. I think these groupings touch on the range of emotional experiences I've had as an engineering graduate student. d. I feel that there is a significant and/or impactful component of my emotional experiences as an engineering graduate student NOT captured in the final groupings.	
Were there aspects of your emotional or mental health experiences at [redacted] you did not feel comfortable sharing, whether that be in the survey, interview, or focus group?	-	( ) Yes ( ) No
Please indicate how salient / impactful you felt these emotional experiences were/are as an engineering graduate student, using N/A for those not applicable or the open response for those you think were applicable but not present in the focus group final responses.	a. External Supports b. Individual c. Isolated & Singled Out d. Milestones e. New Experiences f. Otherness and Whiteness g. Overwhelmed and Unsure h. Quarantine Life i. Other Experience not shared [open response]	(1) Very Salient / Impactful (2) Salient / Impactful (3) Somewhat Salient / Impactful (4) Not Salient / Impactful [Not Applicable]
Based on the groupings presented, please rank them in order of what you perceive to be the most salient and impactful emotional experiences.		(1) Least Salient to (8) Most Salient

Appendix C

Appendices for the Quantitative Study (Chapter 5)

This section provides the appendices for quantitative study exploring the relationship between the culture of engineering and engineering graduate students' self-reported mental health (Chapter 5). The following figures detail the instruments for mental health measures of *anxiety*, *depression*, and *flourishing* before presenting the correlational heat maps for items used in the regression analyses.

GAD-7 Anxiety

Over the last two weeks, how often have you been bothered by the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Feeling nervous, anxious, or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it is hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid, as if something awful might happen	0	1	2	3

Column totals _____ + _____ + _____ + _____ =

Total score _______

If you checked any problems, how difficult have they made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
☐	☐	☐	☐

Figure C-1. Screenshot of full GAD-7 (Spitzer et al., 2006).

Over the *last 2 weeks*, how often have you been bothered by any of the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

(For office coding: Total Score ________ = ________ + ________ + ________)

If you checked off *any* problems, how *difficult* have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very difficult	Extremely difficult
☐	☐	☐	☐

Figure C-2. Screenshot of full PHQ-9 from (Kroenke et al., 2001; Pfizer Inc., 1999; Spitzer et al., 1999).

Below are 8 statements with which you may agree or disagree. Using the 1–7 scale below, indicate your agreement with each item by indicating that response for each statement.

7 Strongly agree
6 Agree
5 Slightly agree
4 Mixed or neither agree nor disagree
3 Slightly disagree
2 Disagree
1 Strongly disagree

I lead a purposeful and meaningful life.
My social relationships are supportive and rewarding.
I am engaged and interested in my daily activities
I actively contribute to the happiness and well-being of others
I am competent and capable in the activities that are important to me
I am a good person and live a good life
I am optimistic about my future
People respect me

Scoring: Add the responses, varying from 1 to 7, for all eight items. The possible range of scores is from 8 (lowest possible) to 56 (highest PWB possible). A high score represents a person with many psychological resources and strengths.

Figure C-3. Screenshot of full Psychological Well-Being Scale (PWB; Diener et al., 2009; Oishi & Biswas-Diener, 2009).

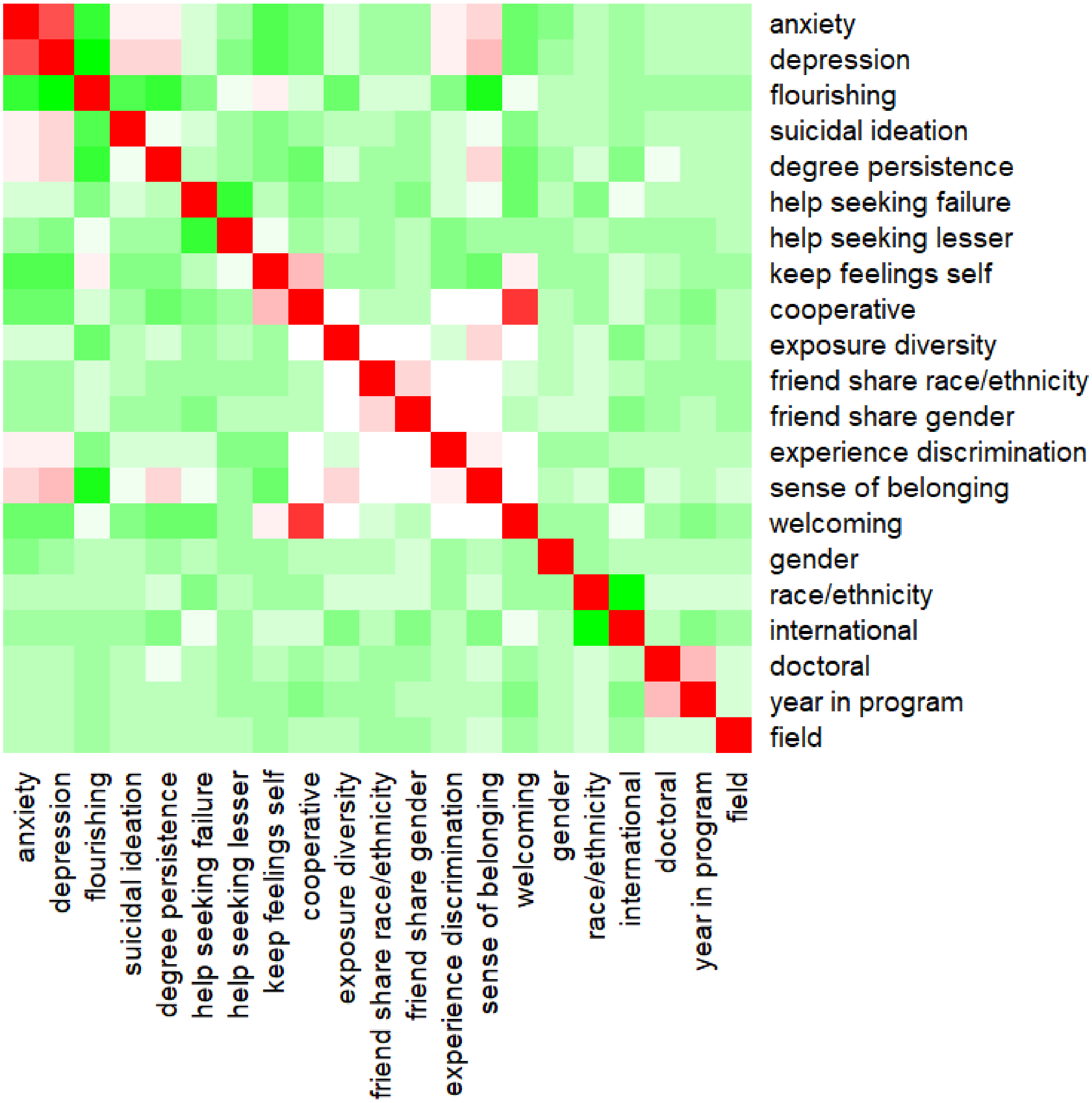

Figure C-4. Heat map between outcomes of interest and covariates for the engineering graduate student population.

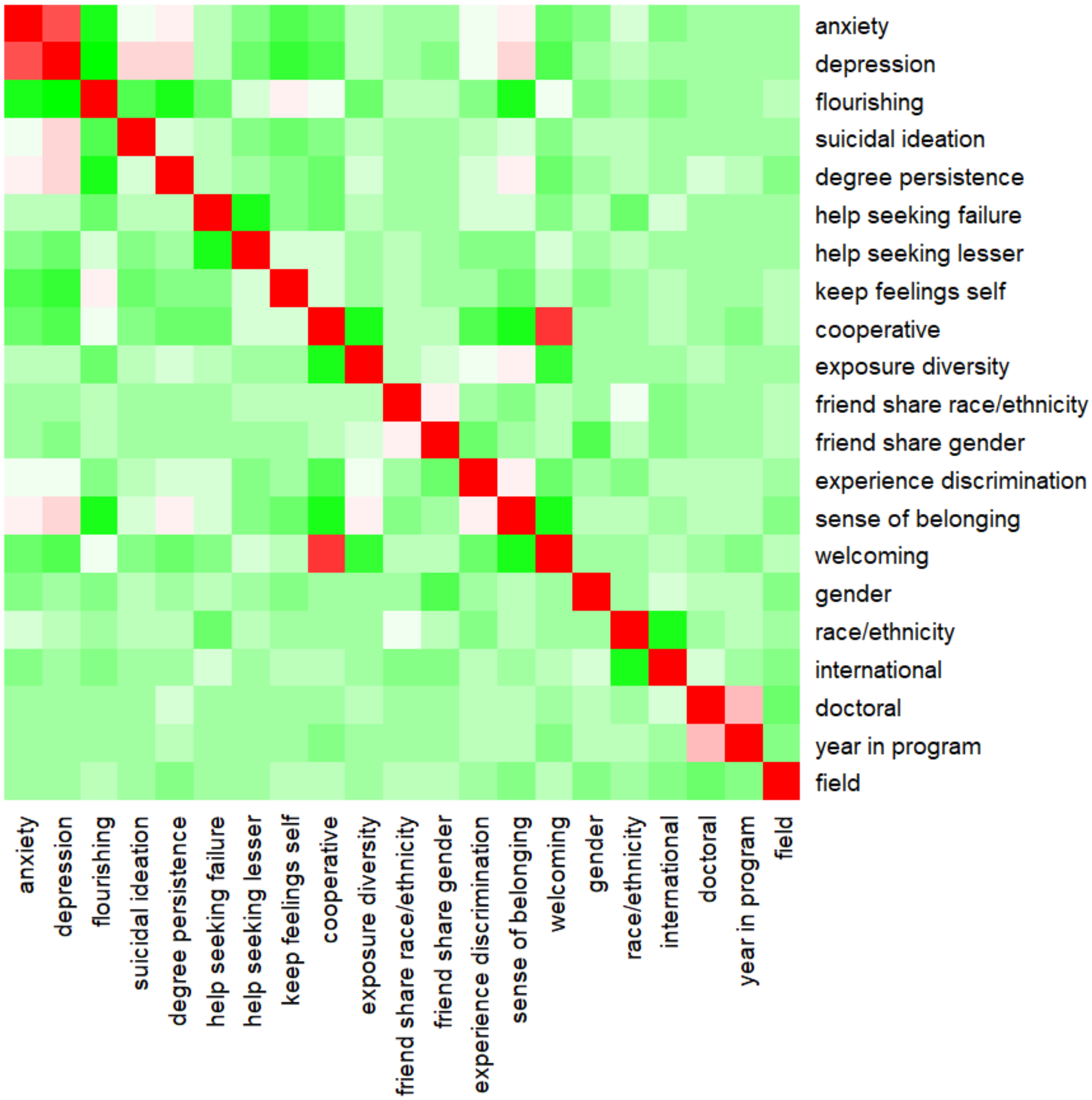

Figure C-5. Heat map between outcomes of interest and covariates for the full graduate student population.

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