

Overlapping Coping Mechanisms: The Hidden Landscapes of Stress Management in Engineering Doctoral Programs*

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As many as 70% of engineering graduate students in the United States consider departing their master's and doctoral programs at any given time. This strong consideration for attrition relates to the chronic stress these students experience in graduate school and the engineering discipline's normalization of stress in the name of academic rigor. The ongoing mental health crisis in higher education in the United States leads us to consider what stressors do engineering graduate students have to contend with and how are they coping with these stressors to improve their experiences and remain in their programs. In this work, we modify the COPE Inventory to be applicable to a graduate student context and explore these students coping mechanisms. Through semi-structured interviews with $n = 42$ engineering graduate students, content analysis, and an abductive approach, we determine the stressors including advisor relationship, research, department, questioning departure, negative mental health, and systemic stressors that our participants experience and the variety of coping mechanisms and coping styles they use to reduce these stressors. Results show that participants often combine coping mechanisms to manage their stress. The coping landscapes in this study visualize these combinations. The widespread use of multiple coping mechanisms at any given time indicates that engineering graduate students are actively trying to reduce their stress and that they must work hard doing invisible labor to persist through graduate school. Teaching students how to establish open communication with advisors and faculty and promoting support structures for students to know they are not alone in their experiences would greatly benefit engineering graduate students and improve retention and persistence in graduate programs.

Keywords: engineering graduate students; attrition; coping; mental health; stressors

1. Introduction and Literature Review

Attrition at the graduate education level, which can be defined as any premature departure from a student's intended graduate degree, is high yet understudied. Reports indicate that attrition rates range from 40–60 percent across doctoral disciplines [1] in the United States. Although engineering attrition rates are slightly lower, with 35 percent of women, 24 percent of men, and as many as 57 percent of African American students departing [2, 3], nearly 70 percent of engineering doctoral students in the United States consider attrition from their PhDs [4]. These high rates of attrition consideration indicate underlying issues in higher education that require exploration. The National Academies has encouraged this exploration through a call to action [5] for research related to graduate STEM education, including graduate student experiences and graduate policy, to address topics like attrition and mental health concerns in graduate education. Exploration of these topics

specifically within an engineering context is still necessary, however. This is because lack of funding and lengthy time to degree completion, two common reasons for attrition from graduate programs, are less prevalent in engineering as upwards of 80 percent of engineering graduate students are fully funded [6, 7] and they complete their degrees in shorter time frames (average of 4–6 years) compared to other disciplines [8]. Even with these beneficial academic circumstances, engineering-specific attrition rates and considerations remain relatively high, suggesting there are additional contributing factors.

One such potential factor that has increasingly concerned educators and counselors is graduate student mental health. While the onset of the Covid-19 pandemic furthered concern for students' mental health and increased overt discussions on the topic in higher education, higher education was experiencing a growing mental health crisis long before this [9, 10]. This is highlighted by the National Academies' particular emphasis of

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mental health in their call to action [5] prior to the pandemic. The mental health crisis is especially concerning for graduate students because this group is up to 6 times more likely to struggle with anxiety and depression than the general United States population [11, 12]. Engineering students are more likely to deal with depression and anxiety when compared to other disciplines [13] and compared to national averages [14]. Graduate engineering students are also the least likely to seek professional help for these issues than students from other disciplines [15, 16]. These students' experiences with negative mental health effects can increase their considerations of attrition from graduate programs [17, 18].

Up to two-thirds of graduate students report high levels of stress resulting from their enrollment in graduate school [19, 20]. Literature indicates that the chronic stress these students are experiencing in school contributes to poor mental health and attrition [21–23] and can interfere with milestone achievement and research performance [24]. Some of the most widely studied academic stressors include research and assistantships [19, 25, 26], advisor relationships [27–29], coursework [19, 30], and poor work-life balance [18, 31]. Students who identify with marginalized groups contend with added systemic stressors such as racism, sexism, discrimination, and microaggressions [18, 22, 32–34] that can exacerbate a general lack of sense of belonging in higher education [35, 36]. Systemic stressors are especially concerning in engineering because of the White, male-centric nature of the discipline [37] which can increase the likelihood of experiencing these stressors. The normalized culture of stress within engineering [38] further raises concerns over engineering graduate students' experiences with stress.

Due to this prolonged stress, graduate students require stress management techniques in the form of coping mechanisms to navigate the unrelenting stress they experience in graduate school. While there is extensive research on the coping mechanisms undergraduate students use to manage general stressors [39–45], significantly less research has been conducted relating to graduate students' coping mechanisms. Existing literature indicates that graduate and undergraduate students cope differently with stressors [46], as graduate students are considerably more likely to seek support to manage stress. Researchers in teaching [47], nursing [48], and psychology [26, 30, 49] have quantified graduate students' stress and subsequent coping mechanism in their respective fields, all finding that support-seeking is the most prevalent coping mechanism. In engineering, however, researchers have not extensively characterized the relationship

between stress and coping or how engineering graduate students generally cope. Many of the studies that discuss engineering do so in the context of comparing engineering to other disciplines in STEM, finding that engineering students are the least likely of STEM students to seek professional support to cope with stress, depression, or anxiety [15, 16]. When literature studies engineering students' coping exclusively, it centers the undergraduate student perspective [14, 41, 50]. There is a scarcity of research that centers how engineering graduate students cope with the stressors they face in graduate school. We posit that such a study is beneficial to researchers, faculty, administrators, and graduate students to develop a greater understanding of common coping mechanisms and the effect stressors have on these mechanisms through a disciplinary lens. As such, this study seeks to answer the following research question:

What coping mechanisms are engineering graduate students using to manage particular graduate school stressors?

2. Theoretical Framework

Though it has been adopted into conversational, everyday language, coping originates as a complex psychological theory to understand how individuals manage stress. In their seminal works, Lazarus [51] and Folkman [52] developed the transactional theory of stress and coping. This theory asserts that an individual's behavior is determined by a continuous relationship between the individual and their environment and is composed of two processes: the appraisal process and coping. During the appraisal process, the individual continuously evaluates their environment for perceived threats, appraising how stressful they find those environmental factors. If one of those factors is interpreted as stressful, then the individual enters the coping process. During the coping process, the individual responds to the stressor in a way they determine to be appropriate. How someone copes with a stressor, however, is context dependent and can influence whether something is considered a stressor in the future [53, 54]. For example, if an individual copes with a stressor and it produces a positive outcome, then they may be less inclined to consider that situation stressful if they encounter it again. If an individual responds to a stressor and the outcome is negative, though, they may view the stressor as more stressful in the future or choose to cope in a completely different way the next time they encounter the stressor [54]. While the transactional theory of stress and coping begins with the appraisal process and is followed by the coping

process to manage a stressor, the coping choices can influence the appraisal process in future situations.

Carver et al., [55] specifically explored the coping process of this theory. Their aim was to further understand the different ways that people cope with stress. To do this, they designed the COPE Inventory [55, 56], a scale of coping mechanisms that can be used to manage stress. The inventory is grounded in Lazarus and Folkman's theory [52] and was developed from the perspective that coping mechanisms are not inherently independent of one another. Instead, individuals' coping mechanisms can and often do influence each other depending on the stressor being managed. A benefit of the inventory is that it can be applied to understand how people cope with stress generally or how they cope with specific stressful situations [55]. It is one of the most prevalent scales used to study coping and has been applied in a variety of research contexts from cancer research [57–59] to higher educational research [30, 42, 60–63].

The most updated versions of the COPE Inventory [64], shown in Table 1, contains 16 coping mechanisms. Psychologists often group coping mechanisms like these into broader categories to understand individuals' general coping styles. One such grouping commonly used when operationalizing the COPE Inventory is categorizing coping mechanisms into problem-focused, emotion-focused, or dysfunctional coping styles. Problem-focused coping is when an individual uses a coping mechanism to attempt to directly change the stressful situation [52, 65]. Emotion-focused coping, on the other hand, is when an individual attempts to reduce the distressing emotions that are associated

with the stressful situation [52, 65]. Dysfunctional coping is commonly referred to as avoidant coping and refers to an individual's attempt to drive attention away from the stressful situation [66]. In Table 1, we show which coping style each of the coping mechanisms in the COPE Inventory belongs to based on prior literature [55, 63, 67–69].

3. Methods

This qualitative work is part of a larger IRB-approved, NSF-funded, nationwide mixed-methods study to understand attrition at the graduate engineering level. This study explores the experiences of engineering graduate students and their attrition considerations.

3.1 Participant Recruitment and Selection

To recruit participants for this study, we emailed the graduate student coordinators and/or department heads, depending on available contact information online, of every engineering discipline at the top-50 engineering PhD granting university as per ASEE's 2018 Engineering by the Numbers report [70]. In this email, we asked these administrators to forward a description of this research study with a link to a recruitment survey to their graduate student listservs. The Qualtrics recruitment survey asked respondents to indicate their graduate degree program and demographic information including number of years in graduate school, race/ethnicity, gender, and citizenship status. Because this study was part of a larger study on graduate-level attrition, we also asked respondents their consideration on leaving their graduate degree with or without a degree. The survey concluded with a question gauging respondents' interest in participating in a follow-up interview to talk about their experiences in graduate school. In total, 620 graduate students completed the survey.

We used maximum variation sampling [71] for race/ethnicity, gender, number of years in graduate school, and intensity of attrition considerations to select participants for this study. Because engineering is a predominately white, male field [37], this type of sampling allows us to capture the stories of participants who have marginalized identities in engineering. Additionally, all participants were U.S. citizens or permanent residents. This choice was deliberate because literature indicates that international students have stressors including language barriers, cultural influences, and visa considerations that can impact their experiences and considerations for departure from programs differently [72]. We believe these should be considered and studied in-depth, but that was beyond the scope of this particular work. Thirty-eight of the total

Table 1. COPE Inventory coping mechanisms and corresponding coping styles

Coping mechanism from COPE Inventory	Coping Style
Active coping	Problem-focused
Use of instrumental support	Problem-focused
Planning	Problem-focused
Restraint	Problem-focused
Suppression of competing activities	Problem-focused
Acceptance	Emotion-focused
Use of emotional support	Emotion-focused
Humor	Emotion-focused
Positive reframing	Emotion-focused
Religion	Emotion-focused
Behavioral disengagement	Dysfunctional
Denial	Dysfunctional
Venting	Dysfunctional
Mental disengagement	Dysfunctional
Self-blame	Dysfunctional
Substance use	Dysfunctional

Table 2. Number of participants who identified with different demographics including race/ethnicity, gender, and number of years in graduate school (total n = 42)

Race/Ethnicity	Number of Participants
Asian	2
Black/African American	2
Hispanic/Latinx	2
White/Caucasian	30
Multi-racial	6
Gender	Number of Participants
Woman	24
Man	16
Gender non-conforming	2
Years in Graduate School	Number of Participants
1–2	15
3–4	18
5+	9

participants in this study were recruited through the Qualtrics recruitment survey. Because the larger aim of this work was to capture graduate students' experiences with attrition considerations and recruiting students who have already departed their graduate program is difficult, we used snow-ball sampling to recruit an additional 4 participants who had departed from their PhD programs. In total, there were n = 42 participants in this study. The demographic composition of the participant pool can be found in Table 2. In this table, we show participants' self-reported race/ethnicity, gender, and number of years in graduate school.

3.2 Data Collection

Data collection was done through semi-structured interviews conducted by two researchers including the first author. The interview protocol was validated through multiple pilot studies and similar questions had been used in previous qualitative studies within this research group. In the interviews, the researchers asked participants to share their experiences throughout graduate school, including their decisions to pursue engineering and graduate degrees, their relationships with their advisor, lab mates, and peers, whether they felt stress or pressure in graduate school and how they dealt with those, and their thoughts on leaving their graduate program. The two researchers conducted the first two interviews together to ensure that they were on the same page about the interview questions and the protocol for conducting the interviews. The remaining 40 interviews were conducted separately by the interviewers based on which interviews aligned with which interviewer's schedule. Interviews lasted between 60 and 90 minutes and were conducted via the Zoom videoconferencing platform with audio recording. At the end of each interview, the

participant was encouraged to choose their own pseudonym and a pseudonym was assigned to them if they preferred not to choose one. Each participant was compensated with a \$10 Amazon gift card after their interview. Audio recordings of each interview were transcribed through a secure transcription service and all identifying information was removed during transcription verification.

3.3 Data Analysis

Data analysis for this study was conducted in two rounds through a constructivist paradigm [73]. In the first round, two researchers used content analysis to identify the coping mechanisms participants applied to manage the graduate school experiences and stressors they described. The COPE Inventory (Table 1) served as an *a priori* framework for this coding process. While the COPE Inventory served as the basis for the codebook in this round of analysis, the coping mechanisms were modified through an abductive approach [74] to align with our participants' unique experiences within the context of graduate engineering education. The researchers removed the coping mechanism *Venting* from the list of potential coping mechanisms because the interviews were set up in such a way that participants would not really be venting about their feelings on stressful situations. Instead, they were reflecting on those situations and talking about how they overcame those challenges or managed the stress. Although the interviews were not able to capture that coping mechanism, the researchers still believe this could be a way of coping with graduate school experiences, just not applicable for this study. The researchers combined the coping mechanisms *Use of instrumental support* and *Use of emotional support* into a broader support category because participants consistently failed to differentiate between instrumental and emotional support and discussed these two forms of support as one when describing how they leaned on support networks to cope. Additionally, the researchers added two coping mechanisms *Balance & boundaries* and *Pursuing non-research activities* to the codebook as these themes naturally emerged in the coding process and were specific to the graduate education context. The modified version of the COPE Inventory used as the codebook in the first round of analysis can be found in Table 3. Along with the 16 coping mechanisms, this table also provides the definition of each mechanism and the coping style each mechanism represents. Because support is a combination of the two types of support in the original COPE Inventory, they are classified as a hybrid coping style. *Balance & boundaries* and *Pursuing non-research activities* are coping mechanisms that emerged specifically in our

Table 3. Modified COPE Inventory with definitions and corresponding coping styles used for first round of interview analysis.

Coping Mechanism	Definition	Coping Style
Active coping	Taking actions to address or confront the situation or problem	Problem-focused
Planning	Thinking about what steps to take or making action strategies to address the situation or experience	Problem-focused
Restraint	Delaying or waiting until the time is appropriate to make a decision or act on a situation	Problem-focused
Suppression of competing activities	Focusing on only one thing (usually work) at the expense of other aspects of one's life	Problem-focused
Support	Seeking or receiving emotional comfort, advice, or help towards a situation from others	Hybrid
Reframing	Intentionally shifting perspective or interpretation of situation/experience	Emotion-focused
Acceptance	Tolerating the current situation and learning to live with it	Emotion-focused
Humor	Making jokes about or making fun of the situation or experience	Emotion-focused
Religion	Leaning on one's religious beliefs or spirituality to help manage a situation or experience	Emotion-focused
Behavioral disengagement	Physically reducing efforts or giving up attempts to deal with the situation or experience	Dysfunctional
Mental disengagement	Cognitively disconnecting from the situation to protect emotions, avoid responsibilities, or distract oneself	Dysfunctional
Denial	Rejecting or refusing to accept the situation	Dysfunctional
Internalizing	Attributing blame or negative thoughts to oneself about the situation or experience	Dysfunctional
Substance use	Using alcohol or other drugs to manage distress related to a situation or experience	Dysfunctional
Balance & boundaries	Doing things or setting boundaries to maintain mental, emotional, or physical health and work/life balance	None
Pursuing non-research activities	Participating in service or activities that are fulfilling but one does not benefit from directly	None

graduate student context and their coping styles have not been explored. Because that exploration requires psychological research and thorough statistical testing with large sample sizes that is beyond the scope of this research, these coping mechanisms were not categorized into one of the existing coping styles. Instead, they were intentionally left without a coping style.

The two researchers coded 7 of the interviews to consensus to establish a shared understanding of the codebook. They then coded one interview independently to calculate their inter-rater reliability (IRR) using Cohen's kappa (κ). This calculation allowed the researchers to determine their level of agreement when applying the codebook. The IRR, $\kappa = 0.754$, indicated a substantial level of agreement [75] between the researchers and the researchers separated the remainder of the interviews and coded them individually through a qualitative coding software. Throughout the coding process, confusing excerpts were discussed and coded to consensus by the researchers.

In the second round of coding, the researchers identified the specific stressors participants were discussing throughout their interviews and mapped the coping mechanisms identified in the first round to those stressors. Open and axial coding was used to identify the stressors. This process was led by the first author and the stressors were developed through engagement with existing litera-

ture on graduate school stressors and discussions with other members of the research team. Prior literature indicated that advisor relationships [27, 29], research responsibilities [25, 26], and systemic stressors like racism or sexism [13, 22] can impact graduate students' experiences and cause stress. As such, these stressors were included and expanded on during the axial coding process. The open coding process generated mental health stressors related to managing depression, anxiety, or PTSD developed during graduate school. The first author also found that participants described their questioning of whether to persist in or depart from their graduate program as something that stressed them out. Therefore, questioning departure also became a stressor at this stage of the coding process. The themes, their definitions, and example excerpts were shared with the research team and discussed to provide clarity and ensure they aligned with participants' descriptions of their experiences. In total, there were 6 major stressors during this round of coding. These stressors, their corresponding definitions, and the number of participants who experienced each stressor can be found in Table 4.

3.4 Limitations

In this work, we recruited participants through voluntary recruitment measures to understand their experiences with attrition and persistence considerations, a potentially extreme and/or

Table 4. Stressors related to engineering graduate school experiences along with definitions and number of participants (out a total of 42) who experienced each stressor

Stressor	Definition
Advisor (n = 39)	The relationship someone has with their advisor, including the advisor's expectations for their productivity and communication styles
Research (n = 41)	Someone's lab environment, including difficult working relationships with their lab mates, ability to do and interest in their research
Department (n = 40)	Stress due to classes, PhD milestones, and interactions with people in someone's department (faculty, classmates, cohort)
Questioning Departure (n = 42)	Stress of thinking about whether the person should depart their PhD program with/without a Master's degree or persist in their program
Negative Mental Health (n = 26)	Managing depression, anxiety, PTSD, etc. that is onset during graduate school
Systemic Stressors (n = 16)	Experiencing racism, sexism, discrimination, ageism, or microaggressions or feeling like you don't belong in your department because of your identities

highly emotive situation. Therefore, there is likely self-selection bias within our participants, as only those willing to share their experiences and those who experienced attrition considerations are represented here. This work also purposefully sampled only U.S. citizen and permanent resident students. This creates an inherent limitation of the international student perspective but was done because literature indicates that the experiences of international students in graduate school are more complex because of cultural and language barriers and visa considerations among other factors [72]. Though this study used maximum variation sampling to recruit participants, there was not a large representation of participants with Latinx, Black, or Asian identities. This likely results from the engineering field's predominantly White culture [37]. However, we did have an overrepresentation of women participants' compared to the general trends of engineering. This work may also not offer a comprehensive list of all possible stressors or ways of coping with said stressors in a graduate education context. Finally, many of the interviews were conducted after the onset of the Covid-19 pandemic (between March and September 2020). While this must be acknowledged as a potential influence of participants' experiences, it serves more as a contextual feature for our participants' overall experiences given they had all been enrolled in graduate school prior to the pandemic.

4. Findings

Carver et al.'s COPE Inventory [64] served as an *a priori* framework for analyzing the coping mechanisms of participants in this study. Throughout the first and second rounds of coding, we adhered to ideas about coping mechanisms held by Carver et al. [55], including that coping mechanisms can influence each other, they can be applied to specific stressors, and they should be explored individually before being generalized into broader categories.

Keeping these ideas in mind allowed us to remain open to the potential for multiple coping mechanisms to be used together to manage stress and encouraged further exploration of these connections. Because coping can manifest differently given the stressor, we mapped participants' mechanisms to the specific stressors from Table 4 that they could encounter in graduate school. Interestingly, we found that many participants were using multiple coping mechanisms when attempting to manage any of these stressors. To understand which mechanisms were being combined and how popular these combinations were, we generated what we call "coping landscapes," 3D visualizations for each of the stressors in Table 4 showing the intersections of coping mechanisms used. Because coping mechanisms can be generalized into broader coping styles after they have been individually explored, the coping mechanisms in these landscapes are organized according to their coping style: problem-focused, hybrid, emotion-focused, dysfunctional, or none. As an example, all the problem-focused coping mechanisms are grouped together in the landscapes.

This work focuses exclusively on the coping landscapes of each identified stressor, emphasizing how coping mechanisms are layered to manage these stressors. For information on the individual use of each coping mechanism for the given stressors, refer to our previous work [76]. In this section, we present the coping landscape for each of the six dominant stressors. Although participants sometimes used more than two coping mechanisms to manage their stressors, this was uncommon. Therefore, these landscapes are limited to the intersection of two coping mechanisms used by participants. For each landscape, the x and y axes indicate the coping mechanisms that were used in combination with another mechanism to manage the specific stressor and their corresponding coping styles. The z axis indicates the popularity of each combination of mechanisms by showing the frequency with

which each combination was used. The grayscale color-bar in each landscape visualizes how often each combination is used. Accompanying each landscape is a participant excerpt to illustrate the layering of coping mechanisms for the given stressor. As we adhere to a constructivist paradigm [73] and believe that each participant's journey is unique, these excerpts are simply examples of how coping mechanisms intersect. We do not believe these quotes are representations of all participants' experiences nor are they meant to show "best practices" in how to handle these stressors. Instead, they are just examples of how our participants sought to manage their stressors.

4.1 Advisor Relationship

The coping landscape for advisor stress is presented in Fig. 1. While more than 30 coping combinations were used to manage this stressor, two were most dominant. Of the 39 participants who experienced advisor stress, 11 of them coped by layering Active coping with Support seeking. This was the highest number of participants who used any combination of mechanisms for any of the stressors. This specific combination was also the most widely used for advisor stress. Active coping with Planning was the second most commonly used combination of mechanisms. Overall, Active coping and Support were the coping mechanisms most combined with other mechanisms to manage advisor stress. Participants also regularly mixed coping styles to cope.

For example, the combination of Active coping with Support meant that they used both problem-focused and a hybrid problem- and emotion-focused coping style. While all the coping styles were used in some capacity, problem-focused coping was the most popular style to combine with others.

Eliana, who was a fourth-year student at the time of her interview, purposefully worked to keep her advisor happy at all times and at any cost. She felt this was a necessary step to be able to graduate with her PhD within a reasonable timeline and free of any spontaneous roadblocks. Eliana believed that advisors were ultimately the "gatekeepers" to successful graduation and had witnessed how peers with strained advisor relationships were often forced to complete extra or unrelated work to their dissertation as a manipulation tactic to receive approval to graduate. Because of this, Eliana worked extremely hard to keep her advisor happy, which she believed created a good advisor relationship. Eliana used Planning and Restraint to navigate the stress of maintaining a good advisor relationship while still pursuing her independent research interests in one of her instances of Advisor Stress.

"I have a paper that I'm working on that [my advisor] doesn't know about because I'm just like, 'I will present it to her when it's done, and I will continue doing my other work as well.' But there's this thing that I wanna do and she does not support me and so I'm gonna just do it and I'm gonna keep doing my other work and then when I show it to her and go, 'Hey, I'd like to

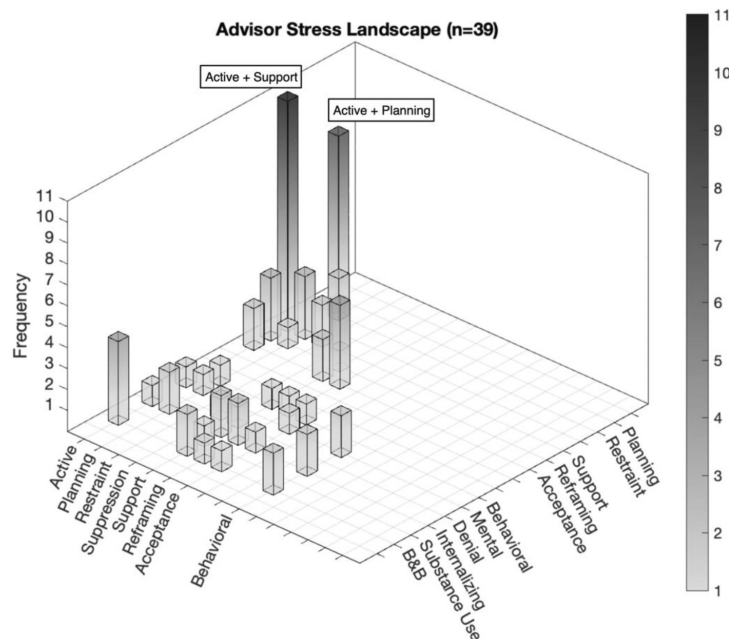


Fig. 1. Coping landscape for advisor relationship stress ($n = 39$ participants experienced this stressor) with the most popular combinations of mechanisms labeled and the frequency with which each combination was used depicted by grayscale color-bar to the right of the figure.

throw your name on this. It's because you're my advisor, I'd like to put your name on it as an author credit.' Just, hopefully, she responds well"

Eliana wanted to pursue an area of research that interested her but knew her advisor would not approve of or allow her to work on this area of research concurrently with her funded research area. So, she pursued this side research without communicating with her advisor, planning exactly when and how she would present the final paper draft of this work. She purposefully restrained from sharing that she was working on this side project to avoid being told she was not allowed to do it and avoid straining her good relationship with her advisor.

4.2 Research

The coping landscape for research stress is presented in Fig. 2 with 41 participants experiencing this stressor. Again, over 30 combinations of mechanisms were used to manage this stressor. Active coping with Support seeking was the most frequently layering. Some participants also coped through a combination of Active coping with Balance & boundaries or Acceptance with Reframing. Active coping was generally the most popular coping mechanism used together with others to reduce research stress. Participants did use all coping styles, preferring to combine problem-focused, emotion-focused, and dysfunctional coping.

Lizard was in her second year of graduate school at the time of her interview and was doubting

whether graduate school was the right choice for her. These doubts had manifested because of her extreme dislike of her research project. She felt stuck with her project, thinking it would not provide a valuable contribution to the community. Lizard had previously tried avoiding her work by focusing on helping her lab mates with their projects but had never directly spoken to her advisor about how much she disliked her project or the stress this was causing, eventually affecting her intentions to continue in her program. Ultimately, Lizard used Support and Active coping as a last resort to improve her Research Stress.

"Eventually, with encouragement from other grad students, I told [advisor]; I was like 'I'm starting to really not enjoy this [research]. I don't like it anymore. I'll keep trying but I'm not really happy about it.' If it works, it'd be great. If it was successful I get it but I don't feel like trying anymore and so eventually, I think that coupled with a different expert weighing in and helping me and her feedback, we dropped the project."

Lizard leaned on her lab mates for support, speaking to them about how unhappy she felt with her research and how it was affecting her graduate school experience. With their help, she felt encouraged and empowered to have an honest conversation with her advisor about the research situation. Lizard eventually initiated a conversation with her advisor where she explained how she was feeling and how the project was failing to produce mean-

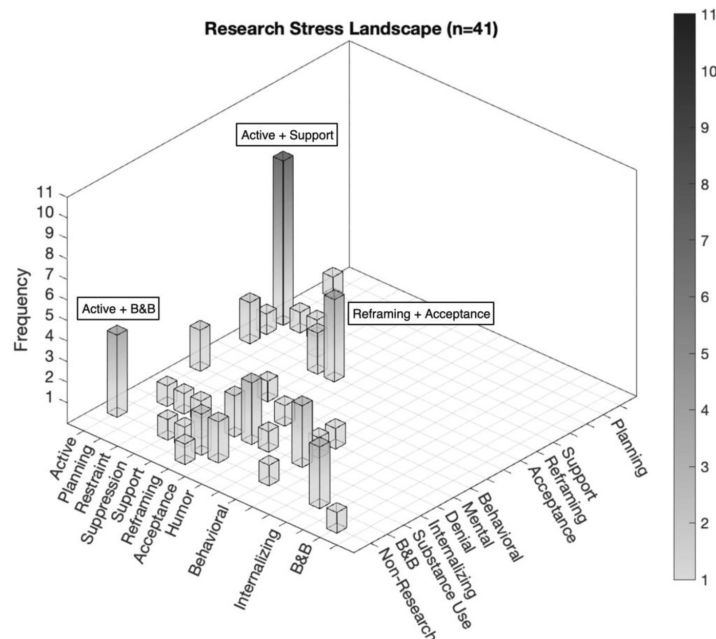


Fig. 2. Coping landscape for research stress (n = 41 participants experienced this stressor) with the most popular combinations of mechanisms labeled and the frequency with which each combination was used depicted by grayscale color-bar to the right of the figure.

ingful results. Through this conversation, Lizard was able to switch to a new project and described feeling much more optimistic about her research and ability to persist in school.

4.3 Department

The coping landscape for departmental stress is presented in Fig. 3. More than 30 combinations of mechanisms were used by the 40 participants who experienced this stressor. The dominant combination, however, was again Active coping with Support seeking. Participants also applied Acceptance with Active coping or Acceptance with Reframing. To reduce departmental stress, participants preferred to combine Active coping or Support with the other coping mechanisms. Although participants operationalized all coping styles, combinations between problem-focused and dysfunctional coping were most dominant.

James, who was in his third year, had a particularly difficult time connecting with people in his department. He self-identified as an extrovert and had been looking for a social support network since he enrolled in graduate school. He described being frustrated with the department's lack of effort and interest in helping graduate students create meaningful connections and felt stressed because of the ensuing social isolation. He was coping with these challenges through Acceptance and Active coping.

"But it was nice when [undergraduate university] would host like barbecues or whatever. And I think

there's less incentive for universities to do that for grad students, 'cause I think a lot of grad students don't care about that stuff. Like I said, a lot of people are very focused on their research, they wanna get that finished and they wanna do the best work that they can do in this limited amount of time. And I think that's totally valid, it's just unfortunate for me, who likes to be a bit more social, and I've had to look elsewhere, I joined a rock-climbing club at the University"

James accepted that his department did not feel inclined to create opportunities for graduate students to connect with each other because they believed the students were generally disinterested in socializing and would rather focus on their research. Because he was an extrovert by nature and was tired of feeling lonely, James actively sought out a community outside his department to satisfy his need to have social support networks.

4.4 Questioning Departure

The coping landscape for questioning departure stress is presented in Fig. 4. Because this study was part of a larger study on graduate-level attrition, every participant experienced this stressor. Participants used 30 combinations of mechanisms to cope with the stress of questioning departure from their graduate programs. The two most dominant combinations were Active coping with Planning and Reframing with Planning. Reframing and Planning were the most popular coping mechanism used in combination with others to reduce this stressor. Overall, problem- and emotion-focused

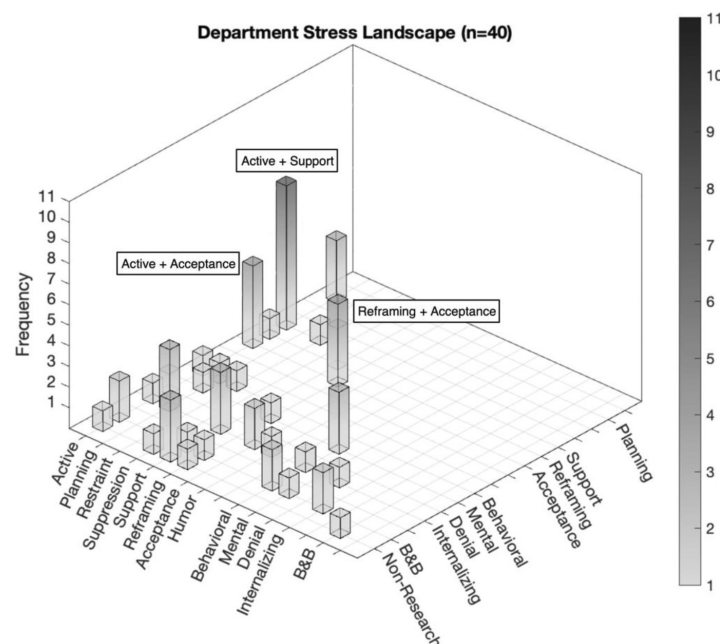


Fig. 3. Coping landscape for department stress ($n = 40$ participants experienced this stressor) with the most popular combinations of mechanisms labeled and the frequency with which each combination was used depicted by grayscale color-bar to the right of the figure.

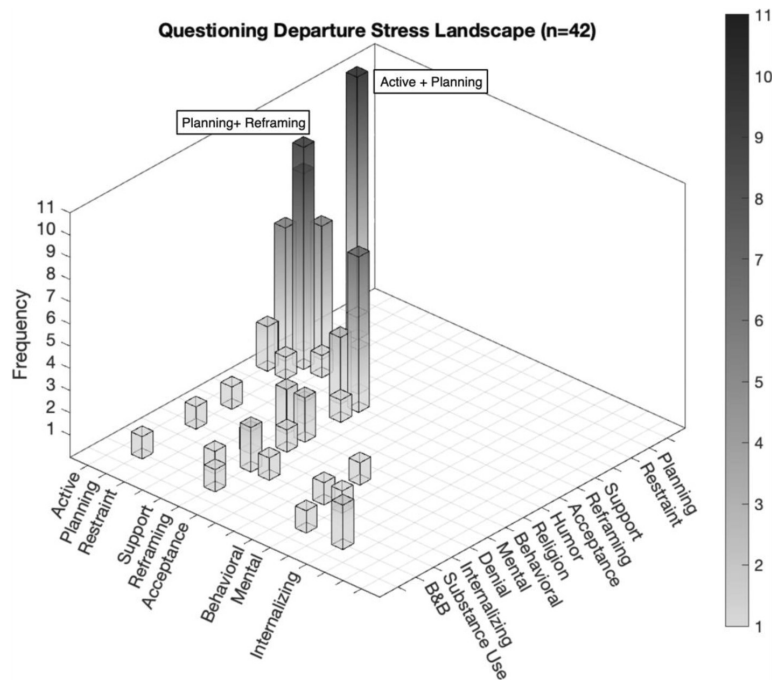


Fig. 4. Coping landscape for questioning departure stress ($n = 42$ participants experienced this stressor) with the most popular combinations of mechanisms labeled and the frequency with which each combination was used depicted by grayscale color-bar to the right of the figure.

coping styles used individually or mixed with other styles were most prevalent.

Cactus, who eventually departed their PhD after four years in graduate school, had questioned whether to persist in their degree since their first year. This uncertainty of whether to stay or go led to higher stress levels, which were only exacerbated by the unwelcoming nature of their engineering department due to their gender identity. For many years, Cactus tried to convince themselves to persist through the degree to manage the increased stress they associated with questioning. Eventually, they realized their career interests had changed and the PhD was no longer worth getting, which eliminated their stress of questioning.

“But all those [negative] experiences [throughout grad school], plus learning a lot of other things made me realize that I didn’t really want to be in a position where I’m primarily working with other PhDs or pursuing academia and really the only reason for me to get a PhD is if I’m going to go into academia. And I don’t wanna do that anymore. So yeah, I left. And I knew I wasn’t going to pass the qualifying exam this time. I didn’t even really try. I was gonna leave before [even taking the exam]. . . . I’m surprised I stuck around that long and it’s mostly due to my great advisor and good social networks. Post first year was just a continuous series of wanting to leave . . . I was forcing myself to stay, and I probably would have just kept fighting to stay despite all the stuff that was happening, but once the pandemic hit, it was just like, ‘Wait, I don’t actually have to put up with this stuff and this

isn’t what I want to do anymore.’ And so I just started checking out of my grad program”

As Cactus stressed over whether to stay or go, they coped using Support, Mental disengagement, Reframing, and Behavioral disengagement. During the first couple years of their PhD, they leaned heavily on their support network as they forced themselves to persist in their degree. They mentally “checked out” of their degree program during this intense period of questioning, avoiding their PhD departmental milestones. Ultimately, though, Cactus began reflecting on their experiences and reframing what they imagined their career to be, which helped them make the decision to leave school. Cactus chose not to even try studying for their qualifying exam once they were making their decision because they did not see any benefit to putting in their best effort for something that would no longer matter. All these mechanisms helped Cactus manage their stress related to Questioning Departure and influenced their decision-making process.

4.5 Negative Mental Health

The coping landscape for negative mental health stress is presented in Fig. 5. Over 25 combinations of mechanisms were used. As seen in Fig. 5, the two most prevalent coping mechanisms used in combination with other mechanisms to reduce this stres-

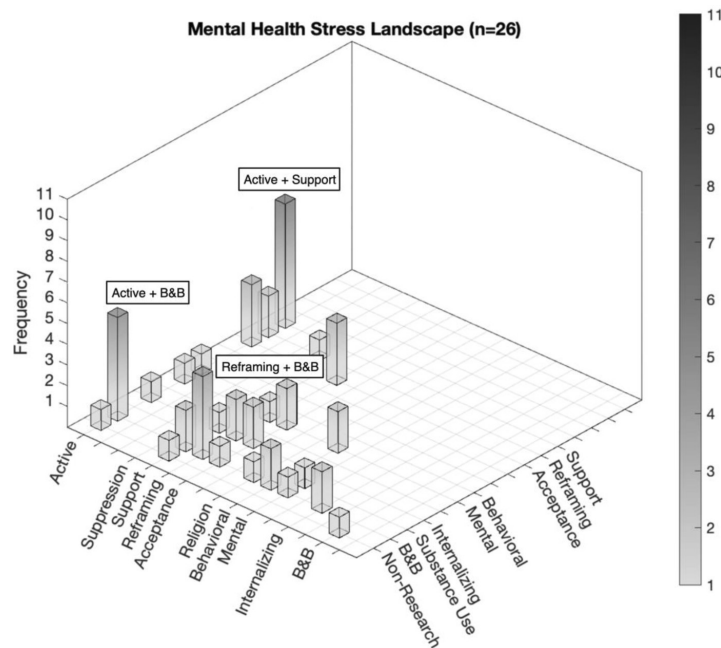


Fig. 5. Coping landscape for negative mental health stress ($n = 26$ participants experienced this stressor) with the most popular combinations of mechanisms labeled and the frequency with which each combination was used depicted by grayscale color-bar to the right of the figure.

sor were Active coping and Balance & boundaries. Active coping with Support, Active coping with Balance & boundaries, and Balance & boundaries with Reframing were the most popular combinations. When managing this stressor, Active coping and Balance & boundaries were individually layered with other mechanisms more than any of the other options. Both problem- and emotion-focused coping styles were often mixed to cope with negative mental health stress.

Alice, a fifth-year student, experienced anxiety and depression from his first year of graduate school. His depression became more severe during his second and third year because of difficulties communicating with his advisor, a strong dislike of his research, and a general dislike of university and departmental culture with regards to supporting students. His deep depression strained his relationships with his friends and peers and caused him stress because he knew something was wrong in the way he was feeling but felt he could not do anything to improve his situation.

“... something was not right [with my mental health]. Like people should not be feeling the way that I felt in terms of just miserable all the time. And yeah, I mean like I definitely like I kinda like isolated myself a little bit more at those times ... I didn't really see much [of my friends in my cohort] my second or third year, not because they weren't still my friends but because I kinda just like chose to not be around them ... I was just like so bummed out that like, I didn't want to be around people and then because I was bummed out

bum them out, you know? ... I definitely drank a lot [to manage it all] ... So I kind of hung out with lawyers a lot, um, to just like, not be around engineers or not be around people. Cause like, you know, you run into a person from your department and they're like, Oh, how's it going? And you're just like, yeah, it's fine but you're really not fine ... so just try to avoid situations where anybody would care at all to ask me about my research.”

To try and cope with his depression, Alice used Active coping, Mental and Behavioral disengagement, and Substance use. He intentionally stopped spending time with his friends to avoid bringing them down emotionally and, instead, made an active choice to socialize with people outside his department. In doing so, he felt he was able to remove himself from situations where he made others sad or had to be forced to pretend he was happy. He worked to mentally and physically remove himself from anything related to his toxic environment, turning to alcohol during this time to help him manage his depressive feelings.

4.6 Systemic Stressors

The coping landscape for systemic stressors, which include racism, sexism, discrimination, and micro-aggressions, is presented in Fig. 6. Notably, this stressor was experienced exclusively by women and gender-nonconforming participants. These participants used 20 combinations of mechanisms to manage systemic stressors, with Support seeking and Reframing being the dominant combination.

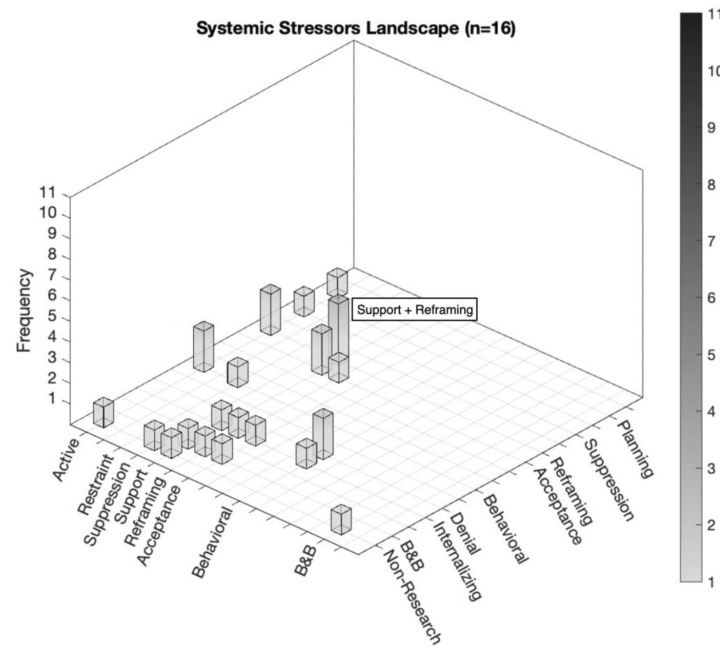


Fig. 6. Coping landscape for systemic stressors ($n = 39$ participants experienced this stressor) with the most popular combinations of mechanisms labeled and the frequency with which each combination was used depicted by grayscale color-bar to the right of the figure.

These were also the two most popular coping mechanisms chosen by participants to layer with other mechanisms. Although all coping styles were operationalized to reduce this stressor, combinations with emotion-focused coping were the most common.

During her five years of graduate school, Yara experienced many Systemic Stressors. She left her first PhD program because of sexist and classist remarks from her peers and department faculty. At her second PhD program, she experienced racial discrimination from her peers and advisor, micro-aggressions related to her race and gender, and sexual harassment. Because of these experiences, Yara developed PTSD and became extremely disenchanted with academia as an entity. To cope with these Systemic Stressors and the ensuing PTSD, Yara used Reframing and Support.

“And in some ways it has been empowering and positive that I’ve learned about institutionalized barriers and things like that in school, because I probably wouldn’t have understood the magnitude unless it affected me this personally, or it affected someone else I knew this personally, and it’s been great to, over time, it’s taken a lot of time, but I found some very nice people. It’s been a small group, but I found some really, really nice people that I can connect with who understand these experiences, and those friendships I very much cherish.”

Yara reframed her experiences with racism, sexism, and sexual harassment as learning opportunities

that encouraged her to empathize with others who dealt with similar stressors. She felt compelled to find a support group of women who could understand her experiences firsthand to feel validated in those experiences. This group ultimately helped her manage her PTSD as well.

5. Discussion

This work contributes to current discussions in engineering education research related to master’s and doctoral student persistence and attrition in two main areas. First, this study is one of the first to map this population’s coping and stress and visualize this qualitative work. The majority of literature on stress and coping has focused on undergraduate students, STEM students generally, or graduate students in fields that require people to extensively support others (i.e. nursing, psychology, and teaching). While the characterization of engineering master’s and doctoral students’ stressors and coping mechanisms is novel, the presentation of this data is also unique. Existing literature on stress and coping has collected and analyzed data through quantitative methods like surveys and statistical analyses. Unlike those studies, this work explores these topics through a qualitative approach where the qualitative data is visualized into three-dimensional graphs to improve readability and accessibility of the data. Qualitative excerpts from participants are also included to solidify an under-

standing of how engineering graduate students apply coping mechanisms. Presenting data this way can help researchers, students, faculty, and administrators gain insight from these graduate students as to how they are coping with stressors in graduate school and map how these coping mechanisms manifest in students' everyday experiences.

The purpose of this study was to understand how engineering graduate students were coping with stressors that could arise as they progressed through graduate school. To do this, we modified the COPE Inventory [64] to increase its applicability to the experiences of graduate students. Through existing literature, we also identified common stressors for graduate students including advisor relationships [27–29], research [19, 25, 26], and systemic stressors like racism or sexism [13, 22, 34, 36]. Using these frames of reference, we mapped how graduate students coped with given stressors, finding that students use multiple coping mechanisms simultaneously to try and manage their stress. This is a primary finding of this paper, contributing to the research community's understanding of how engineering graduate students attempt to manage graduate school stress and how they navigate attrition considerations and persistence.

This study is among the first to highlight the multifaceted nature of coping and the spectrum of coping mechanisms and coping styles that graduate students apply in an endeavor to minimize the chronic stress [20, 21] they experience throughout graduate school. Participants worked extensively to manage their stressors, often combining multiple coping mechanisms in an effort to more effectively reduce stress. Combining coping mechanisms was popular among participants, as the minimum number of combinations for any given stressor was 20 combinations of any two mechanisms. This finding is noteworthy, as it and the figures provided in the results section show that participants are making very concerted efforts to find ways to actually manage their stressors. These coping efforts are one form of emotional labor requiring extensive energy and often going unrecognized. Spending significant time doing this invisible labor when trying to determine the right combination of mechanisms to effectively reduce stressors can lead students to feel burnt out in graduate school [21] and can ultimately reduce the quality and quantity of work these students are capable of doing. The widespread use of combinations of coping mechanisms also indicates that participants are making efforts to be resilient against the stressors they experience. Extensive literature in engineering education has described student resilience as a positive attribute [77–80]. However, there is a growing body

of literature related to students' experiences with discrimination that views the term resilience as a negative [81, 82]. These researchers argue that advocating for student resilience in situations related to discrimination puts the responsibility of preparing for and coping with these situations on the individual students instead of addressing the true problems, the systemic racism and sexism that the higher education system is predicated on [83–85]. While having resilience is important to some aspects of graduate school, as it teaches students to progress past experimental failures or publishing rejections inherent to research, it should not be required or expected of students in all aspects of their experiences. This is because it is also a form of invisible labor that puts the onus on the student to solve problems that may be systemic, such as racism, sexism, chronic stress, or abusive advisors.

Interestingly, every coping mechanism was combined with another to manage the array of stressors of graduate school. While this highlights that there is a spectrum of coping mechanisms that students use and there is no one prescribed way for students to cope, there are favored coping mechanisms. One such favored mechanism is Active coping, which is when a participant makes a deliberate effort to problem-solve their stressor. More than any other mechanism, Active coping was participants' preferred coping mechanism to combine with others and it was commonly used to manage every stressor. Because engineering curricula are known to promote learning of problem-solving skills [86], the widespread use of this coping mechanism among engineering graduate students could result from the skills they are learning as they obtain their degrees. In the classroom, students are being trained to evaluate problems and find solutions that can directly mitigate these problems. These students may naturally be applying these problem-solving skills to other areas of their lives, especially those within the academic environments from which they first learned those skills, to try and reduce their academic stressors.

Combining multiple coping mechanisms is also important because it highlights the combinations of coping styles participants use to manage their stressors. Problem- and emotion-focused coping styles, which respectively are attempts to address stressors head-on and to reduce uncomfortable feelings associated with stressors [65], were the most popular coping styles for our participants. However, participants also regularly used dysfunctional coping, which was an attempt to avoid the stressful situation altogether [66]. While this work does not endeavor to determine or promote the goodness of certain coping styles over others, there is concern over the general use of dysfunctional

coping. These avoidant coping mechanisms can lead to negative outcomes for students when leaned on too heavily. Recalling Alice's way of coping with negative mental health, we see that the reliance on mental disengagement combined with substance use to avoid the depressive feelings he was experiencing in graduate school led him to alcoholism to numb the feelings and be able to mentally check out of this environment. As a direct result of using these coping mechanisms, Alice became a self-described alcoholic in graduate school.

Finally, highlighting the additional stressors identified through open and axial coding of participant interviews is important. Existing literature indicates that dealing with advisor relationships, research, coursework, racism, sexism, or discrimination can increase graduate students' stress levels [19, 22, 27]. There is also work linking graduate school to chronic stress [20, 23], emphasizing the ongoing mental health crisis for students in these environments [9], and suggesting these attribute to students' considerations of attrition [17]. However, none of these studies explicitly link mental health or attrition considerations to stress. This work is, therefore, the first to suggest that dealing with mental health concerns or questioning whether to persist or depart from their programs cause students stress. These links to stress are directly based in our participants' descriptions of them as stressful experiences that they are trying to cope with. It is important to consider these as potential stressors for graduate students because they are, first, extremely pervasive in graduate school and, second, require students to dedicate large amounts of energy to them in order to be able to progress through their degrees.

6. Implications

From this research, we see several areas where our findings can be translated to stakeholders throughout the engineering graduate education environment. This work is relevant to faculty, administrators, and students. The key takeaway from this work is that graduate students are working very hard to be resilient and cope with stressors, which is evidenced by their widespread use of combinations of coping mechanisms to manage each of the advisor, research, department, questioning departure, negative mental health, and systemic stressors. While resilience is often considered a positive characteristic, we argue that it is negative in this context. This is because students are forced to be resilient to systemic problems, placing blame and responsibility on the individual students rather than drawing attention to the root cause of

the problems: i.e. the association of engineering rigor with chronic, prolonged stress and diminished mental health [38]. Because the onus is exclusively on students to resolve their stressors in whatever way possible, the students end up spending large amounts of time applying different combinations of coping mechanisms to manage their stressors. With support from administrators, faculty, and other graduate students, however, they could reduce the time spent concerned with these stressors and, instead, use that time to be more productive at work, produce higher quality work, and allow themselves to enjoy life outside of graduate school. As such, we focus the implications of our study to ways in which these groups can increase student support.

The first step to holistically support engineering graduate students is for administrators, faculty, and the students themselves to acknowledge the systemic issues associated with higher education: including how higher education was developed for the few and was not intended for students with diverse identities [83–85], how engineering was and continues to be a predominantly White, male discipline [37], the power dynamics that are inherent in advisor-advisee relations [87], and how the engineering discipline promotes high stress environments in the name of rigor [38]. When we acknowledge that these systems were created to support those already privileged and with resources readily available and not to support those who are equally capable and elite but have not been offered the same resources for success, we can begin to question the structures that hold these systems up, including how qualifying exams are conducted, hiring practices, student enrollment criteria, and implicit biases. Being introspective also allows people to begin feeling comfortable with the idea of having difficult and uncomfortable conversations about abuses of power from advisors and faculty or instances of racism, sexism, discrimination, or microaggressions. Unraveling this idea that higher education is and always has been a meritocracy is a vital first step to then providing tangible support to students.

One of the most effective ways for faculty and administrators to support students is to provide them with avenues and resources to establish open communication. For instance, departments, colleges, and universities could establish structures such as designating people, providing anonymous feedback drop boxes, and organizing "town hall" events for people to voice concerns about different systemic issues. These include concerns with abusive advisors, experiences with or witnessing racism, sexism, verbal, sexual, or physical abuse, or feelings of discomfort brought on by interactions with

others in their discipline. Although many universities already have some of these structures in place, there is a need to further advertise these modes of communication, either through bulletins, the student handbooks, or periodic reminder emails for example, to ensure that graduate students actually know about them. Establishing administrative and faculty points of contact within departments for students to be able to safely and anonymously discuss issues with advisors, lack of support throughout their qualifying or candidacy examinations, or why they might be considering leaving their programs could also be beneficial, giving students a space and an audience where they can feel seen and heard and voice concerns or receive advice from an outside perspective. Students would also benefit from resources that teach them how to establish open communication with their advisors and mentors about these issues. One way to do this would be to provide a seminar for first year graduate students on the topic of direct and open communication with faculty or how to have difficult conversations with a boss at work. Students would learn how to broach conversations about funding, research, work expectations, and stress and how to talk about mental health, questioning departure, or discrimination experiences with their faculty advisors.

Establishment and promotion of peer-mentoring opportunities would provide students with internal support networks to support one another and reduce the reliance on faculty or administrative support. Through these opportunities, students could share how they handle difficult advising or research situations, how they manage classes and research expectations, and who to go to when struggling with mental health or if they experience discrimination. Students would also have a space to share their emotions and experiences with each other and could learn that they are not alone in their mental health struggles or their questioning departure. Finally, departments could work with university psychological counseling to provide students with workshops geared towards learning how to effectively apply coping mechanisms to stressful experiences in order to mitigate the need to use too many coping mechanisms at once and the use of avoidant coping mechanisms that can be detrimental for mental and physical health. In these workshops, students would have the opportunity to learn to reflect on their current coping mechanisms and think about whether those coping mechanisms are actually serving them and helping them feel less stressed. To encourage reflective practice, students could ask themselves or each other questions like,

“How do I normally deal with [insert stressor]? How do I feel when I deal with it in that way? Is this helping me reduce my stress?”

7. Conclusion

Through interviews with 42 current and former engineering graduate students, we explored the stressors engineering graduate students experienced and visualized the combinations of coping mechanisms they used to manage these stressors through coping landscapes. In this work, we found that participants combined each of the 16 coping mechanisms available in the modified COPE Inventory with other coping mechanisms to manage advisor, research, departmental, questioning departure, negative mental health, and systemic stressors. Students' favored coping mechanism to combine with others was Active coping, which is when people attempt to problem-solve their stressor. The widespread use of this coping mechanism may result from students' experiences working through the engineering curriculum, which heavily promotes problem-solving skills. While participants were building resilience and attempting to individually manage their stressors, we argue that resilience in these situations is not something that should be strived for and promoted. Most of these stressors are due to systemic problems in the higher education system related to the idea that graduate education is a meritocracy and that engineering disciplinary rigor requires students to be stressed. Therefore, asking students to find ways to cope with these common stressors puts the burden on the individual students without acknowledging and scrutinizing the educational environment. To reduce the invisible labor that students must do to cope with these stressors, faculty, administrators, and departments should establish and teach open communication and promote support structures for engineering graduate students. Future work should examine other stressors students may have to contend with in graduate school, how they cope with those stressors, and the amount of time students spend trying to manage stressors.

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