

Coping Landscapes: How graduate engineering students' coping mechanisms correspond with dominant stressors in graduate school

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ABSTRACT

The purpose of this paper is to characterize the coping landscapes that engineering graduate students use to manage specific stressors of graduate school. As recent reports indicate that graduate students are up to six times more likely to struggle with depression and anxiety than the general population, turning attention to well-being and stress in research and practice is an important part of supporting graduate students. Engineering graduate students have the added stress of being in a discipline that normalizes stress culture in the name of academic rigor. There is currently little research that seeks to understand how engineering graduate students cope to reduce unpleasant emotions associated with common stressors. In this paper, we determine the coping mechanisms graduate students use when managing advisor relationships, their research, their department, any thoughts on premature departure from their programs, negative mental health, and systemic stressors. Using data from semi-structured interviews with $n = 42$ graduate engineering student participants discussing their experiences in graduate school, we identified that graduate students cope in layered ways that correspond with different stressors. These findings hold value in ongoing discussions of engineering students' mental health and inclusive practices within the discipline. Faculty and departments will be better equipped to identify and understand students' coping mechanisms, perhaps leading to well-being initiatives that can support student mental health and, in turn, aid in retention of engineering graduate students.

INTRODUCTION AND LITERATURE REVIEW

Graduate student attrition rates are high, yet understudied: Some studies estimate that attrition rates are between 40 and 60 percent across doctoral programs [1]. In engineering, attrition rates are approximately 24 percent for domestic men, 35 percent for domestic women [2], and as high as 57 percent for African American students [3]. These high rates are indicative of underlying issues within the higher education system. To better understand these potential issues, the National Academies published a call to action [4] recommending (among other foci) research on graduate student mental health and well-being within graduate science, technology, engineering, and math (STEM) disciplines as a necessary part of recruitment and retention of graduate students and the future PhD-holding workforce, including the professoriate.

Graduate student mental health is of particular concern because of the mental health crisis among students in the higher education system. Literature indicates that engineering students have a higher likelihood of dealing with depression and anxiety compared to other disciplines [5] and national averages [6], and graduate students are up to 6 times more likely to experience depression and anxiety compared to the general population [7], [8]. The chronic stress of graduate school is one of the most influential reasons students experience poor mental health and leave their graduate programs [9]–[11], as up to two-thirds of graduate students report high levels of stress due to graduate school [12], [13]. Some of the most well-documented academic stressors for students include advisor relationships [14]–[16], assistantships and research [12], [17], [18], and coursework [12], [19]. Students who identify with marginalized groups must deal with added systemic stressors like institutionalized racism, sexism, discrimination, and

microaggressions [5], [9] that can exacerbate a general lack of sense of belonging [20]. Systemic stressors are particularly concerning within engineering because of the White, male-centric nature of the discipline which increases the likelihood of experiencing these stressors within engineering. These stressors can also contribute to poor mental health and increased rates of attrition for students affected by them [21], [22].

During their enrollment, students experience a wide range of stressors for a prolonged period, which requires them to employ stress management techniques called coping mechanisms. While there is extensive literature that describes the healthy (e.g., exercising) and unhealthy ways (e.g., alcohol abuse) in which undergraduates cope with general stress [23]–[27], there is less literature related to graduate students specifically. Research does indicate, however, that graduate students cope with stress in potentially different ways to undergraduates [28]. Graduate students, for example, use support seeking more than any other coping mechanism [29]–[34] and are significantly more likely to seek support to manage stress compared to undergraduate students [28].

Researchers in nursing, teaching, and psychology fields have quantified the levels of stress and the coping mechanisms used to manage this stress within their disciplines [18], [19], [35]–[37], but researchers in engineering have not extensively studied the relationship between stress and coping within the discipline. The little work that has been done shows that engineering graduate students are the least likely to seek professional support to cope with high levels of stress and negative mental health effects compared to students in other STEM and humanities disciplines [38], [39]. There is a scarcity of research focused specifically on engineering students' coping mechanisms. To date, there is no work that maps the ways in which engineering graduate students cope with specific stressors like advisor relationship, systemic stressors, or even their decision-making process when considering attrition and not just general stress. We posit that such a study will help researchers, faculty, administrators and graduate students more fully understand the effects of stressors on student coping mechanisms through a disciplinary lens. As such, this study seeks to answer the following research question: What are engineering graduate students' coping landscapes when dealing with particular graduate school stressors?

THEORETICAL FRAMEWORK

Coping is, in itself, a theoretical framework to understand how people manage their stress, although the term has been applied in colloquial language in ways not fully consistent with the theoretical bases for the theory. In their seminal works, Lazarus [40] and Folkman [41] established the transactional theory of stress and coping. These works set the foundation for coping as a psychological theory. In this theory, a person's behavior is marked by the continuous relationship between the person and their environment and is composed of two processes: the appraisal process and coping. In the appraisal process, the person assesses perceived threats or challenges by continuously evaluating their environment. During this time, the person is appraising whether they consider aspects of their environment stressful or not. The person then implements the coping process to appropriately respond to any stressful situations. Lazarus and Folkman defined coping as “constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person” [41, p. 141]. These coping efforts depend on the context of the situation and are not considered linear. Instead, emotional responses are influenced by the way people cope and

can influence people's future coping abilities [42], [43]. In the transactional theory of stress and coping, determining whether something is stressful is the first step and coping follows to manage the current stressor. However, the coping choice can influence whether something is considered a stressor in the future and how it will be managed.

To further understand the coping process in the theory, Carver et al. [44] created the COPE Inventory, a comprehensive list of coping mechanisms. The inventory was created to avoid oversimplifying individual coping mechanisms as exclusively positive or negative and was grounded in an understanding that the coping mechanisms were not inherently independent and could influence one another depending on the given stressor. The most updated version of the COPE Inventory [45] has 15 coping mechanisms: *Positive reinterpretation and growth*, *Mental disengagement*, *Focus on and venting of emotions*, *Use of instrumental social support*, *Active coping*, *Denial*, *Religious coping*, *Humor*, *Behavioral disengagement*, *Restraint*, *Use of emotional social support*, *Substance use*, *Acceptance*, *Suppression of competing activities*, and *Planning*. It is most often used in surveys and has been applied in a variety of educational research contexts [19], [27], [46]–[48]. For the purposes of this work, we will use the transactional theory of stress and coping to inform our approach to understanding how people cope with stressors. We will use the coping behaviors defined in the COPE Inventory to guide our understanding of the particular coping mechanisms people deploy.

METHODS

In this study, we sought to understand common stressors for engineering graduate students and how students cope with these stressors. This work is part of a larger, NSF-funded, IRB-approved, nationwide mixed-methods study which seeks to understand engineering graduate students' experiences as they relate to Master's-level departure or persistence within graduate programs.

Recruitment and Participants

To recruit participants, we emailed the graduate student coordinators and department heads of each available engineering department at the top 50 PhD-granting universities in the United States as per ASEE's 2018 Engineering by the Numbers [49]. In this email, we asked recipients to forward a description of the research study and the link to our recruitment survey to all the graduate students in their department. Graduate students who completed the recruitment survey answered questions about the extent to which they considered departing from their graduate programs, shared their demographic information, and indicated whether they were interested in participating in a follow-up interview to share their experiences in school.

We used maximum variation sampling [50] for race/ethnicity, gender, number of years in graduate school, and attrition considerations to select a highly diverse participant pool and capture a breadth of experiences. This study focused on U.S. domestic graduate students in engineering, with the understanding that international graduate students experience a host of other stressors (e.g., visa and immigration, language barriers, cultural barriers, discrimination) [51] that require further additional studies. We recruited 38 engineering graduate students to participate in the interview portion of the study through the initial recruitment survey, and four additional participants were identified through snowball sampling. In total, the final qualitative

study comprised $n = 42$ current and former engineering graduate student participants. Table 1 shows the demographic breakdown of our participant pool by gender and race/ethnicity.

Table 1. Number of participants who identified with specific gender and racial/ethnic identities (total $n = 42$).

Gender	Number of Participants
Woman	24
Man	16
Gender non-conforming	2
Race/Ethnicity	Number of Participants
Latinx	2
Black/African American	2
Asian	2
White/Caucasian	30
Multi-racial	6

Data Collection and Analysis

Two researchers conducted the interviews with participants using a semi-structured interview protocol. In these interviews, we asked participants to describe how they chose their advisors and their relationships with their advisor and lab mates, their feelings towards research, if they felt stress or pressure in school and how they dealt with that, and how and to what extent they considered leaving their programs among other things. All interviews were conducted via the Zoom videoconferencing platform and lasted between 60 and 90 minutes. Participants were encouraged to choose a pseudonym at the end of the interview and pseudonyms were assigned to those who decided not to choose. All participants were compensated with a \$10 Amazon gift card as a thank you for sharing their experiences and time. Audio recordings of the interviews were sent to a secure transcription service and all identifying information was redacted.

The analysis of the interviews proceeded in two rounds of coding. First, the coping mechanisms were analyzed through content analysis to identify the ways in which participants coped with the experiences and stressors they described, using the COPE inventory as an *a priori* coding schema. Through an abductive approach, these *a priori* codes were modified to best reflect our data and the context of academic engineering and graduate school in a modified version of the COPE inventory (see Table 3 in the Findings section). As a methodological decision, the researchers based their codebook in the original COPE Inventory coping mechanisms but modified the codebook to be more applicable to graduate students' experiences. They removed coping mechanisms, like focus on and venting of emotions. They also combined emotional and instrumental support into one category and added mechanisms called "balance & boundaries" and "pursuing non-research activities," according to the coping mechanisms that manifested as they conducted their analysis and were specific to the graduate student context. Seven of the interviews were coded to consensus by two researchers to establish a shared understanding of the coding procedures. Inter-rater reliability (IRR) was then calculated using Cohen's kappa (κ) after the researchers independently coded an additional interview to determine the level of agreement in coding. The IRR, $\kappa = 0.754$, indicated substantial agreement between the researchers [52]. The rest of the interviews were coded separately by the researchers using NVivo coding software and any confusing excerpts were discussed and coded to consensus by the researchers.

The second round of coding sought to understand the specific stressors the graduate engineering student participants described and how they coped with those stressors. Open and axial coding was used to categorize participants' major stressors. In total, there were 6 common stressors for participants. This phase was primarily conducted by the lead author, with input from other members of the research team who were familiar with this study and the broader project. Table 2 in the Findings section describes the stressors and their definitions.

Limitations

As with all research, this work has limitations that must be acknowledged. Because participants were recruited through an email survey, and the broader context of the study sought to investigate graduate engineering student experiences related to attrition and persistence, there is potential for self-selection bias in people who have had negative or impactful experiences in graduate school. There is also the potential that some people did not feel comfortable sharing their experiences and, therefore, we are missing important narratives. Though we recruited using maximum variation sampling for race and ethnicity, we did not have a large representation of participants from multicultural or diverse backgrounds, or with intersecting identities. This is likely a result of engineering's predominantly White culture. To this end, we had an overrepresentation of women in our participant pool compared to the general population of women in engineering. We acknowledge that this work may not comprise a fully comprehensive list of all stressors graduate students could possibly experience in their programs, nor all variations of ways graduate engineering students may cope with their stressors. Last, this data was collected during the onset of the Covid-19 pandemic in a season of national turmoil related to politics and ongoing racism. Many of our participants acknowledged that the pandemic added stress to their graduate school experience while we conducted the interviews. As the effects of the pandemic continue to be felt, this is less of a limitation and more a contextual understanding of the altered world that graduate students are navigating. Therefore, we cannot and should not separate the impact of the pandemic from the participants' narratives.

FINDINGS

In this section, we first present the categories of stressors and then the finalized modified inventory of coping mechanisms reflected by our graduate engineering student participants. Table 2 presents the six dominant stressors identified by our participants. While several of them align with themes identified in prior work, such as the pressure related to research (i.e., publish or perish culture) or advisor issues, others are more nuanced and are not well-explored or identified in literature, such as the stress that the act of questioning causes and the stress that experiencing mental health issues can then cause. Table 2 also indicates the number of participants who dealt with each of the 6 stressors out of the total $n = 42$ participants. Because our work was part of a larger study to understand the attrition process, all the participants experienced the stress associated with questioning whether to remain in their program. Notably, every participant who experienced systemic stressors identified as a gender non-conforming person or woman, with over 60% of the women participants in this study experiencing systemic stressors.

Table 2. Stressor categories, resulting definitions and examples of stressors, and number of participants who experienced the stressor.

Stressor and Number of Students Identifying Stressor	Definition
Advisor (n = 39 of 42 participants)	The relationship someone has with their advisor, including the advisor's expectations for their productivity and communication styles
Research (n = 41 of 42 participants)	Someone's lab environment, including difficult working relationships with their lab mates and interest in and ability to do their research
Department (n = 40 of 42 participants)	Stress due to classes, PhD milestones, and interactions with people in someone's department (faculty, classmates, cohort)
Questioning (n = 42 of 42 participants)	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 of 42 participants)	Managing depression, anxiety, PTSD, etc. that is onset during graduate school
Systemic Stressors (n = 16 of 42 participants)	Experiencing racism, sexism, discrimination, ageism, or microaggressions or feeling like one doesn't belong in their department because of their identities

The complete table of 16 coping mechanisms and their corresponding definitions is presented in Table 3. While some mechanisms that use active words in their definition, like seeking support or participating in non-research activities, Active coping is considered a separate coping mechanism where a participant makes a deliberate effort to manage their stressor head-on. That is that the participant directly tries to remove, reduce, or get around the stressor.

Table 3. Modified COPE Inventory with definitions that describe coping behaviors.

Coping Mechanism	Definition
Active coping	Taking actions to address or confront the situation or problem
Planning	Thinking about what steps to take or making action strategies to address the situation or experience
Support	Seeking or receiving emotional comfort, advice, or help towards a situation from others
Reframing	Intentionally shifting perspective or interpretation of situation/experience
Acceptance	Tolerating the current situation and learning to live with it
Denial	Rejecting or refusing to accept the situation
Behavioral disengagement	Physically reducing efforts or giving up attempts to deal with the situation or experience
Mental disengagement	Cognitively disconnecting from the situation to protect emotions, avoid responsibilities, or distract oneself
Drinking	Using alcohol to manage distress related to a situation or experience
Suppression of competing activities	Focusing on only one thing (usually work) at the expense of other aspects of one's life
Balance & Boundaries	Doing things or setting boundaries to maintain mental, emotional, or physical health and work/life balance
Pursuing non-research activities	Participating in service or activities that are fulfilling but one does not benefit from directly
Humor	Making jokes about or making fun of the situation or experience

Religion	Leaning on one's religious beliefs or spirituality to help manage a situation or experience
Internalizing	Attributing blame or negative thoughts to oneself about the situation or experience
Restraint	Delaying or waiting until the time is appropriate to make a decision or act on a situation

Among the 42 participants in the study, all coping mechanisms were employed, and all stressors were experienced, although not every participant experienced all stressors, nor did they employ all coping mechanisms. Table 4 shows an aggregate view of how participants coped with each stressor without showing overlapping coping mechanisms used to manage any given stressor. Support seeking was a prevalent way of coping with all the stressors, as 65% or more participants used it for any given stressor. It was particularly popular for dealing with research stress, as all but one participant who experienced that stressor used it.

Table 4. Number of participants who used the coping mechanism for the given stressor, regardless of if they used multiple coping mechanisms together. The percentage of participants who used the given coping mechanism for each stressor is in parentheses.

Stressor and Number of Participants (out of 42)	Advisor (n = 39)	Research (n = 41)	Department (n = 40)	Questioning (n = 42)	Negative Mental Health (n = 26)	Systemic Stressors (n = 16)
Active	28 (72%)	21 (51%)	22 (55%)	21 (50%)	18 (69%)	10 (63%)
Planning	16 (41%)	5 (12%)	9 (23%)	33 (79%)	0	1 (6%)
Support	32 (82%)	40 (98%)	30 (75%)	33 (79%)	17 (65%)	12 (75%)
Reframing	13 (33%)	15 (37%)	9 (23%)	26 (62%)	9 (35%)	7 (44%)
Acceptance	13 (33%)	16 (39%)	13 (33%)	10 (24%)	11 (42%)	7 (44%)
Denial	6 (15%)	3 (7%)	4 (10%)	3 (7%)	0	6 (38%)
Behavioral disengagement	7 (18%)	10 (24%)	7 (18%)	8 (19%)	3 (12%)	5 (31%)
Mental disengagement	3 (8%)	3 (7%)	7 (18%)	4 (10%)	6 (23%)	0
Drinking	2 (5%)	3 (7%)	1 (3%)	1 (2%)	2 (8%)	0
Suppression of competing activities	4 (10%)	9 (22%)	6 (15%)	0	2 (8%)	2 (13%)
Balance & Boundaries	12 (31%)	25 (61%)	18 (45%)	4 (10%)	17 (65%)	2 (13%)
Pursuing non-research activities	0	2 (5%)	14 (35%)	0	4 (15%)	5 (31%)
Humor	0	2 (5%)	2 (5%)	4 (10%)	1 (4%)	0
Religion	0	1 (2%)	2 (5%)	1 (2%)	1 (4%)	0
Internalizing	10 (26%)	19 (46%)	14 (35%)	14 (33%)	8 (31%)	4 (25%)
Restraint	8 (21%)	2 (5%)	1 (3%)	5 (12%)	0	1 (6%)

Participants often used a layered approach to coping, applying multiple coping mechanisms at a time. In our analysis, we noticed that participants tended to apply different

coping strategies to different stressors. We present this data through what we call “Coping Landscapes,” tables that show the frequencies in which overlapping coping strategies are employed. This depiction is unique and aligns with stress and coping theory [44] in that the stressors influence and are influenced by each other, and the same is true for the coping mechanisms. Although participants sometimes used more than two coping mechanisms at a given time, this happened relatively infrequently, so we represent the coping landscapes in two-dimensional tables that show only how two coping mechanisms intersect. There are six coping landscapes described in this study that correspond to the six dominant stressors identified. After we introduce each coping landscape, we present an illustrative excerpt from the interview data to show how intersecting coping mechanisms related to the stressor manifest. As each participant’s specific journey is unique, these quotes are meant simply as examples of how these mechanisms intersect.

We note that our job as researchers is not to determine whether these coping approaches are good or not, nor whether the participant handles the situation in the ways we would personally recommend. In other words, the quotes do not present ‘best practices’ in handling stressors; they are simply illustrative of how current and former graduate students handle these stressors via various combinations of coping mechanisms.

Advisor Relationship

Table 5 shows the coping landscape for Advisor Stress. Each number in the table represents the number of participants, of the total 39 who experienced Advisor Stress, that used the coping mechanism either individually or in combination with another. The shading in the table corresponds to the frequency density of the combinations of coping mechanisms, with darker shading indicating higher use of the combination. The most common combinations of mechanisms were Support with Active coping, Planning with Active coping, and a tie between Balance & Boundaries with Active coping and Acceptance with Reframing. Many of the combinations included Active coping with another mechanism. To demonstrate how combinations can manifest for individuals, we share Eliana’s experience in how she manages her Advisor Stress.

Table 5. Advisor relationship stress coping landscape: second column indicates the number of participants who used mechanisms independently while the rest of the table indicates the number of participants who used combinations of mechanisms (n = 39). Darker shading indicates higher frequency density relative to the other combinations.

Coping Mechanism	Independent Use	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Active coping	21	–															
2. Planning	6	8	–														
3. Support	25	11	3	–													
4. Reframing	9	3	1	1	–												
5. Acceptance	8	2	–	2	4	–											
6. Denial	4	–	–	1	–	–	–										
7. Behavioral disengagement	3	–	1	1	1	1	–	–									
8. Mental disengagement	–	1	1	–	–	1	–	2	–								
9. Drinking	1	–	–	1	–	–	–	–	–	–							
10. Suppression of competing activities	3	–	–	–	–	–	1	–	–	–	–						
11. Balance & Boundaries	7	4	–	2	1	1	–	2	–	–	–	–					
12. Pursuing non-research activities	–	–	–	–	–	–	–	–	–	–	–	–	–				
13. Humor	–	–	–	–	–	–	–	–	–	–	–	–	–	–			
14. Religion	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		
15. Internalizing	8	1	2	2	2	1	–	2	–	–	–	–	–	–	–	–	–
16. Restraint	6	–	2	2	–	–	–	–	–	–	–	–	–	–	–	–	–

Note: Some participants (n = 3) did not describe advisor relationship stress or corresponding coping mechanisms within their interviews.

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 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.

Research

In Table 6, we present the coping landscape for Research Stress. Here, the numbers represent the number of participants, of the 41 who experienced this stressor, who used either the coping mechanism individually or in combination with another mechanism. The three most common combinations of mechanisms were Support with Active coping, Balance & Boundaries with Active coping, and Acceptance with Reframing.

Table 6. Research stress coping landscape: second column indicates the number of participants who used mechanisms independently while the rest of the table indicates the number of participants who used combinations of mechanisms (n = 41). Darker shading indicates higher frequency density relative to the other combinations.

Coping Mechanism	Independent Use	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Active coping	15	–															
2. Planning	2	1	–														
3. Support	36	8	1	–													
4. Reframing	9	1	–	–	–												
5. Acceptance	10	2	–	2	4	–											
6. Denial	2	–	–	–	–	–	–										
7. Behavioral disengagement	7	2	–	1	–	–	1	–									
8. Mental disengagement	1	–	–	–	–	1	–	1	–								
9. Drinking	2	–	–	1	–	–	–	–	–	–							
10. Suppression of competing activities	6	–	–	–	1	–	–	–	–	–	–						
11. Balance & Boundaries	19	4	–	1	2	2	–	1	–	–	1	–					
12. Pursuing non-research activities	2	–	–	–	1	–	–	–	–	–	–	1	–				
13. Humor	1	–	–	–	–	–	–	–	–	–	–	–	–	–			
14. Religion	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–		
15. Internalizing	13	–	1	–	2	3	–	3	–	–	1	3	–	1	–	–	
16. Restraint	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1	–

Note: One participant did not describe research stress or corresponding coping mechanisms within their interview.

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 meaningful 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.

Department

Table 7 presents the coping landscape for Department Stress. The numbers in this table indicate how many participants, of the 40 participants who experienced this stressor, used the coping mechanism independently or in combination with another. The three most common mechanisms for Department Stress were Support with Active coping, Acceptance with Active coping, and Acceptance with Reframing.

Table 7. Department stress coping landscape: second column indicates the number of participants who used mechanisms independently while the rest of the table indicates the number of participants who used combinations of mechanisms (n = 40). Darker shading indicates higher frequency density relative to the other combinations.

Coping Mechanism	Independent Use	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Active coping	14	–															
2. Planning	4	3	–														
3. Support	27	7	–	–													
4. Reframing	11	1	–	2	–												
5. Acceptance	8	4	–	–	4	–											
6. Denial	3	1	–	–	–	–	–										
7. Behavioral disengagement	1	1	1	–	–	–	–	–									
8. Mental disengagement	3	–	1	–	1	–	–	3	–								
9. Drinking	1	–	–	–	–	–	–	–	–	–							
10. Suppression of competing activities	6	–	–	–	–	–	–	–	–	–	–						
11. Balance & Boundaries	12	2	–	1	1	–	–	2	1	–	–	–					
12. Pursuing non-research activities	12	1	–	3	1	–	–	–	–	–	1	1	–				
13. Humor	1	–	–	–	–	–	–	–	–	–	–	–	–	–			
14. Religion	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–		
15. Internalizing	10	1	3	3	–	2	1	1	–	–	–	2	–	1	–	–	
16. Restraint	1	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–

Note: Some participants (n = 2) did not describe department stress or corresponding coping mechanisms within their interviews.

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.

Questioning

In Table 8, we present the coping landscape of Stress When Questioning whether to depart or persist in school. Because every participant experienced this stressor, the total possible number in the table is 42. The three most common combinations of mechanisms were Planning with Active coping, Reframing with Planning, and Support with Active coping. Combinations for this stressor were primarily clustered around Active coping, Planning, Support, and Reframing.

Table 8. Questioning stress coping landscape: second column indicates the number of participants who used mechanisms independently while the rest of the table indicates the number of participants who used combinations of mechanisms (n = 42). Darker shading indicates higher frequency density relative to the other combinations.

[illegible]

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 and influenced their decision-making process.

Negative Mental Health

Table 9 presents the coping landscape for Negative Mental Health Stress. Each number indicates how many participants, out of 26, used the coping mechanism independently or in combination with another. Combinations of mechanisms were primarily clustered around Active coping combined with other mechanisms and Balance & Boundaries combined with other mechanisms. The three most common mechanisms were Support with Active coping, Balance & Boundaries with Active coping, and Balance & Boundaries with Reframing.

Table 9. Negative mental health stress coping landscape: second column indicates the number of participants who used mechanisms independently while the rest of the table indicates the number of participants who used combinations of mechanisms (n = 26). Darker shading indicates higher frequency density relative to the other combinations.

Coping Mechanism	Independent Use	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Active coping	8	–															
2. Planning	–	–	–														
3. Support	13	6	–	–													
4. Reframing	5	2	–	–	–												
5. Acceptance	5	3	–	–	3	–											
6. Denial	–	–	–	–	–	–	–										
7. Behavioral disengagement	–	1	–	–	–	–	–	–									
8. Mental disengagement	2	1	–	–	1	2	–	2	–								
9. Drinking	1	–	–	–	–	–	–	–	1	–							
10. Suppression of competing activities	1	–	–	–	1	–	–	–	–	–							
11. Balance & Boundaries	9	5	–	2	4	1	–	2	1	–	–	–					
12. Pursuing non-research activities	3	1	–	1	–	–	–	–	–	–	–	1	–				
13. Humor	1	–	–	–	–	–	–	–	–	–	–	–	–	–			
14. Religion	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–		
15. Internalizing	5	1	–	1	2	2	–	–	–	–	–	2	–	–	–	–	
16. Restraint	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Note: Some participants (n = 16) did not describe negative mental health stress or corresponding coping mechanisms within their interviews.

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 Alcohol. 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.

Systemic Stressors

In Table 10, we present the coping landscape for Systemic Stressors. The numbers in the table indicate how many participants, out of 16, used the coping mechanisms independently or in combination with another. The most common combination was Reframing with Support. Because this stressor was not as common among participants, there is a widespread use of combinations without high frequency densities. Participants dealing with this stressor used many combinations of mechanisms to try and cope.

Table 10. Systemic stressors coping landscape: second column indicates the number of participants who used mechanisms independently while the rest of the table indicates the number of participants who used combinations of mechanisms (n = 16). Darker shading indicates higher frequency density relative to the other combinations.

Coping Mechanism	Independent Use	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Active coping	8	–															
2. Planning	–	1	–														
3. Support	10	–	–	–													
4. Reframing	3	2	–	3	–												
5. Acceptance	4	–	–	2	1	–											
6. Denial	4	–	–	–	–	–	–										
7. Behavioral disengagement	3	2	–	–	–	–	2	–									
8. Mental disengagement	–	–	–	–	–	–	–	–	–								
9. Drinking	–	–	–	–	–	–	–	–	–	–							
10. Suppression of competing activities	–	1	–	–	–	–	–	–	–	–	–						
11. Balance & Boundaries	–	–	–	1	1	1	–	–	–	–	–	–					
12. Pursuing non-research activities	4	1	–	1	–	–	–	–	–	–	1	1	–				
13. Humor	–	–	–	–	–	–	–	–	–	–	–	–	–	–			
14. Religion	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		
15. Internalizing	3	–	–	1	1	1	–	1	–	–	–	–	–	–	–	–	
16. Restraint	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–

Note: Some participants (n = 26) did not describe systemic stressors or corresponding coping mechanisms within their interviews.

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, microaggressions 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.

DISCUSSION

In this work, we characterized the coping landscapes for engineering graduate students according to six stressors: advisor relationships, research, department, questioning, negative mental health, and systemic stressors. Our work indicates that students use combinations of coping mechanisms to manage their stressors, introducing our interpretation of “Coping Landscapes,” which has not been previously discussed in literature. As demonstrated by other scholars [28], [32], [34], our participants used Support, individually or in combination with other mechanisms, often to manage their stressors. They most heavily relied on Support to handle Research Stress, looking to their lab mates or colleagues for advice or moral support on how to improve their research environment. Combinations with Active coping in the coping landscapes were very common. We posit that perhaps this coping mechanism is closely related to problem-solving skills, which are integral to engineering curricula. It is not surprising that our participants used this mechanism extensively and consistently to manage their stressors, as this mechanism plays into the strengths of engineering students’ academic training.

Notably, over 60% of the participants experienced stress from Negative Mental Health during their time in school. Almost half of the participants who dealt with this stressor used Acceptance to cope. This aligns with other work [53] that indicates that graduate students expect to be stressed and depressed when they enter graduate school. Coping through Acceptance further supports this expectation because participants were accepting that graduate school brought on depression or increased anxiety and there was not much they could do to avoid it.

While less than half of the participants experienced Systemic Stressors, those who did identified as gender non-conforming people or women. In fact, over 60% of the women in this study experienced Systemic Stressors. They did try to actively cope and find support to manage this, but they also reframed their experiences of racism, harassment, or sexism and sometimes openly accepted these experiences as a normal part of being in the engineering culture. These ways of coping are problematic and unhealthy to the people experiencing the stressors because they normalize negative, non-inclusive, and threatening behavior in engineering.

One of the most important outcomes of this work is that stress (and as an extreme outcome of stress, attrition) is not something that “happens to” graduate students. Through the implementation of coping mechanisms, we see how students try to maintain control of their

situations even when they feel powerless, recalling Eliana's strategy of writing a whole manuscript behind her advisor's back and hoping for the best because she knew she wanted to pursue that area of research, but felt stymied and frustrated by her advisor. Though past literature has alluded to various stressors in graduate programs [18], [22], or perhaps nodded to coping mechanisms pertinent to the academic landscape [12], [19], this study is the first to document the overlapping nature of the coping mechanisms and how they relate to specific stressors for graduate engineering students. Future research could further explore the management of stressors through theories like self-authorship theory [54] or other theories of academic identity or role identity [55] that are often used to explain how graduate students develop their commitments to their roles as researchers and scholars within an engineering context. Certainly, managing the chronic and constant pressures of the academic research economy in engineering are aspects of self-authorship, academic identity, and likely affect professorial intentions, though these aspects are underexplored in existing literature on these topics.

IMPLICATIONS AND CONCLUSION

Through 42 semi-structured interviews, we characterized the Coping Landscapes engineering graduate students use to manage six stressors: Advisor, Research, Department, Questioning, Negative Mental Health, and Systemic Stressors. We used a modified version of the COPE Inventory to guide our coding of coping mechanisms, and showed how the employment of coping mechanisms, and multiple coping mechanisms at a given time, vary in response to the various stressors faced by engineering graduate students. Ultimately, coping is a multilayered process and departments can help students improve their stress levels by discussing healthy and appropriate ways of coping in specific situations.

The implications from this work affect multiple stakeholders in the higher education ecosystem. We see the most value of this work in using the Coping Landscapes to translate the ways in which today's graduate students see their world to the administrators and faculty they work with, who, despite being in academia perhaps for decades, went through graduate school at a much different time and culture in society and academia. Administrators, graduate program chairs and coordinators, research supervisors, and faculty who interact with graduate students can use this paper to gain an appreciation and awareness for how today's graduate students are navigating the current stressors they face. We suggest that graduate faculty reflect on their own experiences as graduate students, but also lean on current literature to illustrate how things may be different for today's graduate students compared to when faculty were undergoing their education, especially as the mental health crisis has become pervasive in the past five years.

Ultimately, this work illustrates specifically how graduate engineering students are trying to improve their chronic and prolonged stress during their time in school by using a variety of coping mechanisms, layering them in different ways that correspond to the different stressors they face. However, graduate students are not always successful in managing their stress, and therefore, formal and informal interventions could help students to either develop healthy coping mechanisms or avoid unhealthy ones. Programs should also create spaces where graduate students can safely discuss their problems, particularly their advisor, research, or department stressors to find support and help improve their situations when applicable, perhaps using the concept of an individualized "Coping Landscape" to help students reflect on how they manage stress and how they might differently or more healthily manage their stress. Most importantly,

the presence of systemic stressors related to structural and cultural sexism, racism, or toxic competitiveness must be acknowledged and addressed by engineering departments to reduce the likelihood of creating non-inclusive and unwelcoming disciplinary environments for students with marginalized identities. Doing so will improve graduate student mental health and, in turn, perhaps, result in increased retention of graduate students.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant #1844878. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the National Science Foundation. The authors wish to thank the participants of this study for being so willing to be open and share their experiences.

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