How Engineering Graduate Students Experience Growth and Fixed Mindset in Complex Research Environment

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How engineering graduate students experience growth and fixed mindset in complex research environment?

1. Introduction and Literature Review

Over the last decade, literature focused on engineering graduate students has well-established issues with well-being [1], overwork [2], stressors [3], and duress that affect their ability to thrive [4], [5]. Repeated and sustained experiences impacting students' thriving can have long term effects on their mental and physical health [6,7], productivity [8], creativity [9], and persistence into future research and academic careers [10], [11]. In sum, the academic environment in which doctoral students are learning and working is fraught with pitfalls.

While the barriers to graduate student thriving are thoroughly explored in higher education literature—including but not limited to advisor, funding, time to degree completion, and social isolation [12]-[16]—in engineering, these stressors manifest differently than in science, social sciences, or humanities: Engineering graduate students are more consistently funded on research assistantships, hold fewer teaching assistantships, and typically work in more social and collaborative research lab environments [17].

Particularly in engineering, most literature has focused at the psychosocial level—that is, how the sociological environment affects individuals' psychological perceptions of their success, ability to thrive, and perceptions of their group [3], [4], [17], [18]. Recent literature ([2], [4], [19], [20]) has illuminated a landscape of stressors and coping mechanisms by which engineering graduate students respond to those stressors. Sallai et al. [21] found that "active coping" mechanisms were most employed by engineering graduate students, potentially a manifestation of an engineering problem-solving mentality. However, given that barriers to thriving are widespread, this paper seeks to turn attention to how engineering graduate students' mindsets influence the ways and strategies in which they navigate barriers. Mindset, or an individual's core beliefs about the malleability of abilities, stress, and attention, affects how they interpret difficulty, regulate emotion, and choose coping responses [22, 23].

Limited literature has explored mindset in engineering graduate students. With respect to graduate students, a few noteworthy studies have explored fixed and growth mindset [24, 25]. For example, Li et al. [25] found that growth mindset moderates the negative effect of stress, acting as a buffer against depression for postgraduate students. Simultaneously, although growth beliefs are linked to more adaptive coping, we know little about how often engineering graduate students actually enact these beliefs or how mindset manifests in their day-to-day lives. Most studies on growth and fixed mindset are quantitative in nature [26]-[28], employing self-reported metrics of growth or fixed mindset. In this work, we seek to situate and operationalize growth and fixed mindset in the specific context of graduate engineering research lab environments—the work and educational spaces where doctoral students spend most of their time. To this end, the purpose of this paper is to examine how growth and fixed beliefs appear in engineering research lab environment and responses to stressors, not just whether students endorse growth on a survey. The specific research question this paper will address is: *In what ways do growth and fixed mindsets manifest in graduate students' perceptions on navigating barriers in graduate school experience?*

2. Theoretical Orientation

The primary lens for this study is Dweck et al.'s social cognitive model of achievement motivation [29] and Burnette et al.'s SOMA model [30], which are the bases for distinguishing growth and fixed mindset (in line with theories of "implicit intelligence" [31] — notably, these theories are *not* about innate capabilities). Dweck's social cognitive model of achievement motivation

positions Implicit Theory as foundational beliefs that orient individuals toward particular achievement goals, which shape effort beliefs, responses to challenge, responses to feedback, social comparison, and attributions for success and failure [30]-[32]. The SOMA model, which stands for setting/operating/monitoring/achieving (with respect to an individual's goals), links and organizes implicit theories with self-regulatory processes [30]. Fixed mindsets, connected with entity theories of traits and behaviors, have also been linked to depression and distress [33]. Indeed, literature shows that a growth mindset can act as a "buffer" against stress, protecting individuals from developments of stagnation thoughts. Empirical findings show that those with a growth mindset relate to lower distress and more active coping [27]. Growth mindset individuals are also less likely to develop significant symptoms of depression or anxiety, even when facing high levels of stress (like academic stress or social challenges) [34]. It is important here to note that we are not interested in 'victim blaming' or proposing a 'bootstraps model' for graduate students to have to thrive despite harmful adversity alone, but instead, we propose that investigating mindset may help illuminate how and why students are making sense of the barriers they encounter in graduate school.

3. Methods

Participant Recruitment and Selection: As part of a larger NSF funded study, we distributed a national survey to graduate engineering students from the top 50 PhD-granting U.S. doctoral programs per the 2022 ASEE By the Numbers report [35]. The survey collected information about characteristics of their research groups and demographic information, including years in graduate school, discipline, gender, and race/ethnicity. We also included multiple short scales to understand graduate students' experiences, including Dweck's "Kind-of-Person" Implicit Theory scale based on [31], [36], to understand how a person's orientation leads to growth or fixed mindset. This scale contains eight survey items to assess an individual's belief that they can change and grow on a six-point rating scale. The last survey question asked if the student would be willing to participate in a semi-structured interview.

Of those that completed the survey in full and elected to participate in a follow-up interview, we used maximum variation sampling for gender, citizenship status, race/ethnicity, majors, years in PhD to select our interview pool. A total of n = 61 graduate students were selected for follow-up interviews. For this paper, with the goal of characterizing evidence of fixed and growth mindset in graduate research group environments, we employed extreme group sampling (n=10) to focus on the participants from the study who held the five highest and five lowest scores on the "Kind-of-Person" Implicit Theory scale. These scores were calculated by averaging the participants' scale item ratings, according to the scoring criteria. A higher average score corresponds with growth mindset; likewise, lower averages correspond with fixed mindset. Participants' mindset scores for are shown in Table 1.

Table 1. Participant information

Participant Pseudonym	Gender	Growth or Fixed Score	Participant Pseudonym	Gender	Growth or Fixed Score
Princess	Woman	5.00 (Growth)	Mari	Woman	1.63 (Fixed)
Serena	Woman	5.00 (Growth)	Doris	Woman	1.88 (Fixed)
Zidane	Man	5.00 (Growth)	Richard	Man	1.00 (Fixed)
Straw Hat	Man	5.00 (Growth)	Judge	Non-binary	1.38 (Fixed)
Ron	Man	4.75 (Growth)	Fig	Woman	2.00 (Fixed)

Data Collection: We developed, piloted, and employed a semi-structured interview protocol to explore graduate students' daily work routines, challenges, and advisor and lab interactions. The semi-structured nature of the interview protocol allowed the interviewers to follow emergent lines of conversation. Throughout the process, the interviewers met with each other and the broader research team to align interviewing styles and decisions. Each interview was conducted and recorded via Zoom and transcribed using a secure professional transcription service. Participants were allowed to select their own pseudonyms.

Data Analysis: We conducted a theoretically informed thematic analysis to identify evidence of growth and fixed mindset beliefs in students' descriptions of their research lab experiences and interactions with advisors, labmates, and peers. While implicit theories are often treated as quantitative scale scores that place individuals along a single continuum, our goal in this paper was to operationalize growth and fixed mindset qualitatively in the context of engineering graduate research. We structured our codebook using Dweck's social cognitive model of achievement motivation [29]. Drawing on this model and related work on mindset processes [22], [32], [37]-[39], we developed seven parent codes for our thematic analysis: ability belief, goal/achievement orientation, effort beliefs, response to challenge, response to feedback or criticism, comparison to others' success, and attributions for outcomes (full codebook in Appendix A). Once the initial codebook was drafted, the first author applied it deductively to a subset of two transcripts, coding segments where students described their lab trajectories, advisor relationships, and experiences of success or struggle. The research team reviewed these early coded excerpts, refined code definitions, and clarified borderline cases, while remaining anchored in the theoretical model to finalize the codebook and analyze the remaining transcripts.

Limitations: Several limitations of this study should be acknowledged. Due to the nature of participant recruitment, there is a potential for students' self-selection bias. It is likely that students who consented to be interviewed differ in important ways from those who did not, which may limit the range of experiences and mindset enactments represented in this analysis. Second, our qualitative subsample focuses on the five participants with the highest and five with the lowest scores on the mindset scale. This extreme case sampling strategy surfaces rich contrasts, but it also narrows the breadth of perspectives and may underrepresent more moderate or mixed profiles. Third, the growth mindset measure that we used for sampling was originally developed for broad use and has recently been critiqued in disciplinary contexts. Finally, interviews were conducted by three members of the research team, who each may have individual approaches to conducting interviews and unique rapport with each participant. Conversations and meetings between interviewers between interviews occurred often to promote alignment of interview methods.

Our analytical approach is designed in part to response to these limitations. By extending beyond the scale scores to interview narratives, we are able to examine how growth and fixed oriented beliefs and enactments manifest in students' day to day descriptions of their research lives. The qualitative data therefore complement the survey results rather than simply restating them.

4. Findings

Drawing on Dweck's social cognitive model [29] and Burnette et al.'s SOMA model [30], we organized our analysis around two foundational beliefs (ability beliefs and goal/achievement orientation) and five enactment processes (effort beliefs, responses to challenge, responses to feedback/criticism, comparison to other's success, and attributions for outcomes). For each code, we identified paired examples of growth and fixed oriented evidence. Interestingly, growth- and fixed-scored participants did not always articulate a corresponding growth or fixed belief in all

contexts. Instead, we identified some contexts where growth-scored participants articulated fixed-oriented beliefs and where fixed-scored participants described a developmental shift toward growth-oriented framings, highlighting the importance of the study's structure to capture these beliefs. In this section, we present representative excerpts to illustrate how these beliefs and processes manifested in graduate students' narratives.

Ability Belief

Ability beliefs capture how students understand their own competence and their potential to improve. In this dataset, students articulated both growth-oriented views of ability as something that develops over time and fixed beliefs about who they can successfully work with. We compared two growth-oriented examples with a fixed-oriented example to illustrate this difference.

Growth Mindset – Ability Belief

Straw Hat: "The very first thing I would say is that I think I've learned to listen to people. During my early days, I used to think I was the most intelligent guy in the room. Now I know that I am probably the like least intelligent guy in the room. It's always a good idea to listen to what everybody is suggesting. I think I've also learned to ask questions. We used to be afraid to ask [teachers] any questions. But now I think I have learned there are no stupid questions. I've learned to ask questions in places where I am confused and that has helped clarify lots of things."

Fig: "I think I have become a lot more confident in myself as a scientist. I think when I first started, I was like, 'I don't know anything, I don't know how to do anything, and also everybody here already knows everything and is so smart and I'm dumb.' And then I came to realize that that was not true… I've definitely become more confident in my own knowledge and my own skills…

Fixed Mindset – Ability Belief

Serena: "And being in academia is getting increasingly harsh and harsh with time, and the pressure on the faculty members is increasing every day, every day to generate more funds, bring in more students, things like that. In industry, you're just responsible for yourself, and you're just responsible for your own work. But in academia, a lot of people are relying on you. Say as a professor, if I don't generate enough fund *(sic)*, I won't be able to pay my students, and that's a big issue. And I do not want to be held back by those kind of pressures. I don't think I'm built for taking that kind of pressure. So I would rather stay in the industry, be in the industry, and stay there."

Growth-oriented ability beliefs emphasized learning, help-seeking, and the sense that ability can be expanded through practice and feedback. Growth scored participant Straw Hat described a clear shift in how he sees his own competence. He explicitly contrasts his early days of thinking he was the most intelligent in the room with his current orientation toward listening and asking questions. Over time, he comes to see himself as someone who seeks input, admits confusion, and actively asks questions. This account reflects a growth-oriented belief that ability is improved through engagement with others and acting on feedback. Another participant, Fig, whose mindset score averaged as fixed, narrated a very different starting point but a similar growth-oriented pathway. Rather than beginning from overconfidence, she began from a belief that she was less capable than everyone around her. Fig learned to recognize her own developing expertise as she conducted more research. Together, these two excerpts show growth-oriented ability beliefs emerging from opposite starting points. In both cases, students describe ability as something that changes through experience, practice, and accumulated evidence of competence, which is consistent with a growth mindset framing of ability.

In contrast, fixed-oriented ability beliefs were often articulated through belief that certain traits required for success were innate. Growth-scored participant Serena described her decision to

leave academia not as a choice of preference, but as a lack of inherent capacity to handle the specific pressures of the field. Her statement reflects an "entity view" of resilience, the belief that one is either built for the environment or not, rather than viewing stress management as a malleable skill that can be acquired.

Goal/Achievement Orientation

Goal or achievement orientation captures what students see as the purpose of graduate school and what "success" means to them. Growth-oriented evidence came from growth-scored participant Zidane, who framed his decision to pursue chemical engineering and graduate study around contribution to society rather than just a degree. Zidane positioned graduate school as a pathway to impact and discovery, not simply a way to prove that he is smart. His goals are contribution-oriented and wants to participate in breakthroughs and innovations.

Growth Mindset - Goal/Achievement Orientation	**Fixed Mindset - Goal/Achievement Orientation**
Zidane: "I wanted to do research and contribute to the society. I chose chemical engineering because there is more scope to do higher studies in this field. Through academia and research, there is a greater chance to contribute to breakthroughs and innovations"	Mari: "Transitioning just into research didn't feel much of a transition, because I kind of viewed it as going from one job to another... This is my new job, with new co-workers." Later, when describing her long working hours, she summarized her motivation as: "It's just time management mixed with trying to do too much because you want to have data presented, get out [of grad school]."

In contrast, fixed-oriented evidence came from fixed-scored participant Mari, who repeatedly described her PhD as a job to get through. For Mari, the central goal was to produce enough data to finish and leave, rather than to deepen understanding or grow as a researcher. Her language emphasizes getting through and getting out, which reflects a performance and outcome driven orientation. Together, these two cases illustrate how graduate students can occupy very different ends of the goal/achievement spectrum. One motivated by curiosity and contribution, the other by accumulation of results to secure the degree.

Effort Beliefs

Growth-oriented effort beliefs represents whether students treated effort as a meaningful pathway to progress, rather than as a sign of low ability. Growth-scored participant Straw Hat described taking on an independent project with a peer in addition to his thesis work. Here, effort is assumed to be instrumental. He and his peer invest time independently, generate preliminary results, and then seek faculty input about publication. He does not wait for direction before acting; instead, he treats faculty feedback as something that comes after sustained effort. This pattern reflects agency, persistence, and a belief that effort can produce outcomes worth sharing, consistent with growth-oriented effort beliefs.

Growth Mindset – Effort Beliefs	**Fixed Mindset – Effort Beliefs**
Straw Hat: "I've been collaborating on an independent project with one of my friends. We try to make some progress on our own and, if we see some good results, we talk with the professor [advisor] and then decide whether to try to publish it.	None observed

We did not identify clear examples of fixed effort beliefs in our ten participants. Students varied in their ability beliefs, goal orientations, comparisons, and attributions, but they consistently endorsed the idea that sustained effort and persistence are required in graduate school, even when they held more fixed beliefs about ability or future academic success. We interpret this absence as meaningful in itself and likely shaped by selection into PhD programs. Students who fundamentally disbelieve in the usefulness of effort are less likely to apply to, enroll in, and persist through engineering doctoral study.

Response to Challenge

Response to challenge captures how students made sense of major setbacks in their PhD trajectories and what those experiences signaled about their future. Across participants, we saw a contrast between treating challenges as information to recalibrate and treating them as evidence of limited long-term potential.

Growth Mindset – Response to Challenge	**Fixed Mindset – Response to Challenge**
Princess: "After I had a very bad experience in my previous group, I thought that the project is important, but the advisor is much more important. With the help of another professor, I joined another group... Now I really like my project, I really like my advisor... That's why I chose to continue my research and my PhD studies in [current group name]."	Doris: "I don't really enjoy doing research and... the work-life balance is a problem... I don't feel like I have been successful at the level that I wanted in my PhD because I didn't have a good start. It becomes difficult to stay motivated... If you're not building those connections and progressing in your research, then it makes me feel like I probably will not be successful if I decide to pursue a career in academia, considering that I already struggled in my PhD."

Growth-oriented responses involved using negative experiences to adjust strategy rather than abandoning or avoiding the challenge. Growth-scored participant, Princess, described leaving a misaligned research group and joining a new one. Princess interprets the very bad experience not as proof that she cannot succeed in the PhD, but as evidence about what she needs in an advisor. Her response to a bad experience was to revise her plan, switch labs, and persist in the program, which showing a growth-oriented response to challenge in which setbacks prompt re-evaluation and new action rather than complete withdrawal.

In contrast, fixed-oriented responses involved treating early struggles as durable constraints on future success. Fixed scored participant Doris reflected on her difficulties in research and their implications for an academic career. For her, an early bad start, weak connections, and stalled progress are taken as evidence that she is unlikely to succeed in academia. Rather than describing new strategies or changes in context, she projects her current struggles forward and lowers her expectations for herself. This forward-looking pessimism illustrates a more fixed response to challenge, where difficulty is read as a sign of limited long-term potential rather than as an opportunity for growth.

Response to Feedback/Criticism

Response to feedback and criticism captures how students interpret evaluative input from advisors and what they do with it. From our participants, we saw students either treating feedback as something they could actively shape and learn from, or as a source of dread that signaled threat and prompted withdrawal from a harmful context. In this conversation, it is important to understand that advisors have immense responsibility in setting the tone for meetings, given the propensity for power disparities and documented instances of abusive advisor relationships. We

note that in these examples, there are aspects of advisor behavior that are both problematic and that students have no control over, we also saw the rhetorical indicators of how different students respond to feedback.

Growth Mindset – Response to Feedback	**Fixed Mindset – Response to Feedback**
Fig: " I also had to learn that if I wanted specific feedback or answers to certain questions, I had to clearly asked for that; he wouldn't just give me feedback automatically. There was a learning curve at the beginning, but now I understand more how he functions, and it makes our interactions a lot smoother."	Princess: "My [ex] advisor's behavior towards me was so bad. Every time I did something wrong or didn't know something, he talked to me like an idiot... Every week we had a mandatory meeting. The night before the meeting, I couldn't sleep; I cried a lot and was very worried about what would happen... It was too much stress for me."

Growth-oriented enactments appeared even among participants who were more fixed overall. Fixed-scored participant, Fig, described learning how to ask for the feedback she needed from a relatively hands-off advisor. She repeatedly emphasized that she had to learn how to manage this relationship, framing advisor communication and feedback-seeking as skills she can develop. Faced with an unstructured, quiet advisor, she did not conclude that she is helpless; instead, she changed her own behavior, such as requesting more frequent meetings, asking specific questions, to get the feedback she needs. This reflects a growth-oriented response to feedback as opportunities in which students adjust their strategies..

In comparison, growth-scored participant Princess described an advising context where feedback was delivered through personal attacks rather than constructive critique. Here, the feedback she received is experienced as humiliation and threat, producing intense anxiety and dread of weekly meetings that eventually contributed to her decision to leave the lab and find a new advisor. On the surface, her avoidance of these meetings could be read as a fixed response to criticism, but in context it functions more like a self-protection in an abusive environment but, analysis through a mindset perspective shows how students can enact growth-oriented responses when feedback is at least workable, and how even growth-minded students may withdraw from situations where criticism is consistently delivered as personal attack rather than as information for improvements.

Comparison to Success of Others

Comparison to other's success captures how students interpret peers' accomplishments and what others' progress signals about their own potential. Across participants, we saw students either using others' success as input for adjusting their own strategies or as evidence that their own work was less valuable.

Growth Mindset – Comparison/Success of Others	**Fixed Mindset – Comparison/Success of Others**
Ron: "I was feeling discouraged because I saw another group doing related research and getting really good results, and I thought, 'Why am I even doing my own research?' My advisor said, 'Don't let that discourage you… I have ideas on how to use their work to synergize our work.' That made me think it would be good if I could accelerate my productivity, so we have more chance to do impactful research."	Doris: "She travels a lot to give talks about what we do in the lab. In those talks, she doesn't talk about my research. She talks about work of other students… That makes me feel like maybe my research is not valued, or my contributions are not viewed the same way as the other students."

A growth-oriented example came from a growth-scored participant Ron who initially felt discouraged when another group advanced quickly on a similar research problem. His first reaction

is classic comparison-based doubt, yet he does not remain in that state. With advisor input, he frames the other group's progress as a resource and a reason to adjust his own pace and strategy. Other's success becomes a cue to improve and collaborate, not a signal that he should quit or that he is incapable.

In contrast, fixed-oriented comparisons appeared when students perceived others' visibility as evidence that their own work was not valued. Fixed-scored Doris described how she felt when her advisor presented the lab's work at her talks. Here, seeing her peers' work highlighted by their advisor leads her to conclude that her research contributions are less important. She does not frame this as something she could clarity with her advisor; instead, she experiences persistent feelings of devaluation and resentment about the other students. This pattern reflects a more fixed comparison stance, in which others' success is taken as a stable indication of her standing rather than as information that could be clarified and used to grow or adjust her trajectory.

Attribution for Outcomes

Attribution for outcomes describe how students explain why their current situation looks the way it does, and whether they view progress and difficulties as tied to effort and development or to unchangeable conditions. Growth-scored Serena attributed her increased autonomy and mutual respect with her advisor to her development over time. Knowledge, respect, and credibility in this case are framed as outcomes of experience and demonstrated competence rather than as traits she either had or did not have from the start. This reflects a growth-oriented attribution pattern, where positive outcomes are explained in terms of skills developed with practice.

Growth Mindset – Attribution for Outcomes	**Fixed Mindset – Attribution for Outcomes**
Serena: "He was pretty hands-on in the beginning when I needed more guidance. But now that I have matured as a researcher, he lets me do my own thing and guides me in the right direction. We have a mutual respect… I have built that foothold that if I am saying something, my advisor knows I am not talking nonsense. I am saying it because I know it."	Mari: "Grad school is a bad time for everyone… Most people in my lab have at least a few instances of things not working like they want them to. It is frustrating to troubleshoot and feel you are stuck."

In contrast, fixed-scored Mari offered a more pessimistic account of graduate school. She portrays graduate school as inherently a "bad time", defined by pressure pitfall, and persistent frustration. The emphasis is on the inevitability of being stuck, rather than on strategies to respond or conditions that might change. Although she does not explicitly say she is incapable, this explanation functions as a stable attribution about outcomes. The experience is bad for everyone, and that is simply how it is. This aligns with more fixed attributions for outcomes, where difficulties are seen as built into the situation rather than as challenges that can be addressed through growth or structural change.

5. Discussion

In this paper, we examined how growth and fixed mindset beliefs manifest in the research lab narratives of engineering PhD students who scored high or low on a mindset scale. Our analysis makes two primary contributions: First, we qualitatively operationalize mindset processes for graduate engineering education, showing how growth and fixed patterns appear within and across individuals; Second, we illustrate how research lab environments can shape and constrain the enactment of these beliefs.

Qualitatively operationalizing mindset in graduate engineering context

Much of the existing mindset literature relies on self-report scales that locate students along a single continuum from fixed to growth mindset. While these scales are useful for creating a baseline of understanding an individual's initial mindset orientation, the scales cannot capture the nuance of an individual's experiences. By theoretically grounding and structuring our codebook around the seven parent codes [22], [29], [32], [37]-[39], we show how specific components of the mindset framework appear in graduate research narratives. Our qualitative approach demonstrates that graduate students' beliefs are layered and context dependent, rather than stably fixed- or growth-oriented. While participants in this study represented the strongest growth mindset and fixed mindset scores from a larger participant pool, we identified instances where participants' beliefs align with their mindset score and where they do not. For example, Straw Hat, who was strongly growth-oriented, described a shift from seeing himself as the most intelligent person in the room to deliberately listening to others and asking questions whenever he is confused. Fig, who scored more fixed, exhibited growth behaviors and beliefs when shifting from feeling less intelligent than others in her PhD to developing and recognizing her knowledge and research skills over time. Both cases illustrate growth-oriented ability beliefs, but they emerge from opposite starting points, one from overconfidence, the other from pronounced self-doubt.

Similarly, several fixed-scored participants described setting boundaries, seeking new advisors, or negotiating feedback in ways that align more closely with growth-oriented enactments than with right fixed patterns. These findings echo Dweck's argument that mindsets are better understood as patterns across domains than as immutable personality traits [40]. In our data, scale scores were useful for selecting participants with contrasting orientations, but the interview reveal a more complex picture: growth and fixed beliefs coexist within individuals and their expression varies across situations and relationships.

We also observed that some beliefs commonly treated as fixed in the literature take different forms in this context. For instance, we found no clear evidence of classic fixed effort beliefs in this subsample. All ten students, regardless of scale score, endorsed the idea that sustained effort and persistence are necessary in graduate school. At the same time, we did identify what might be considered outward fixed beliefs, where growth-oriented students described entire categories of advisors as unsuitable based on perceived mentoring style. This suggests that mindset work in graduate education should attend not only to how students view their own ability, but also to how they view the abilities and change potential of others in their lab environment, particularly the research advisor.

Lab culture as a boundary condition on mindset enactment

Our second contribution concerns the relationship between individual beliefs and the research lab environments in which those beliefs are enacted. In several cases, students who appeared growth oriented in their survey responses and interviews described fixed-like reactions when situated in toxic or highly constrained lab contexts. For example, Princess, who later switched from a harmful lab environment to a more supportive one highlighted her underlying belief and confidence in becoming a researcher being overshadowed by a fixed and toxic lab culture. Conversely, some fixed-scored participants enacted growth-oriented strategies when the environment allowed it. Prior work on "cultures of genius" supports these findings and distinguishes between personal mindset and organizational mindset, arguing that environments that endorse fixed views of ability can push individuals toward defensive, performance-protective behaviors even when they personally endorse growth-oriented beliefs [41]. Taken together, these patterns support the idea

that lab culture functions as a boundary condition on mindset enactment. Individual beliefs matter, but they are expressed within advising relationships, peer norms, and departmental expectations that can either support or suppress growth-oriented behaviors. This finding has important implications for interventions. Efforts that focus solely on training students to adopt a growth mindset or to be more resilient risk placing responsibility on individuals while leaving intact the lab environments that may be reinforcing fixed-oriented norms, such as fear of failure, relentless overwork, or abusive supervisory practices.

6. Implications and Conclusions

This study used a theoretically grounded qualitative analysis to examine how growth and fixed mindset beliefs manifest in engineering PhD students' research lab narratives. By moving beyond a single mindset score and coding students' detailed descriptions of ability, goals, effort, challenges, feedback, comparison, and attributions, we showed that graduate students' mindsets are not best understood as static labels. Instead, growth and fixed oriented beliefs coexist within individuals and are enacted differently across situations. Our findings also suggest that mindset scales can be useful tools for identifying broad orientations, but they are insufficient on their own for truly understanding how mindsets shape the everyday experiences in graduate school. To support doctoral students effectively, educators and advisors need to understand not only whether a student endorses growth or fixed statements on survey, but also what triggers fixed responses, how students interpret challenges, and how lab environments either enable or constrain growth-oriented behaviors. In particular, we found that students with relatively growth-oriented profiles sometimes enacted fixed like responses in toxic or highly constrained lab settings, while fixed scored students sometimes described developmental shifts and growth-oriented strategies when supported. This pattern underscores the importance of lab culture and advising practices as key levers for fostering environments where asking questions, renegotiating expectations, and even switching labs when necessary are seen as legitimate and safe strategies for learning.

For graduate programs and advisors, the implication of this research study is that mindset interventions cannot stop at encouraging individual students to be growth minded. Instead, departments and research groups must attend to the conditions under which growth is possible and safe, including how feedback is delivered, how mistakes are treated, and how students are supported when they encounter serious tensions in their lab environments.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant Number 2414169 and 2414170. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Appendix A: Growth/Fixed Mindset Codebook

Parent Code	Growth Mindset Evidence Definition	GM Definition in Research Lab Context	Fixed Mindset Evidence Definition	FM Definition in Research Lab Context
Ability Belief	Believe that abilities or skills are malleable and can be developed with practice, strategy, or feedbacks	Talk about growing as a researcher, becoming more confident, or gaining competency in weaker areas as they spend more time in the lab	Believe that abilities are innate or fixed, labels self or others as naturals or not cut out for this	Describe themselves as dumb, not a research person, or worries they cannot continue the PhD, or describe others as inherently smart or not suited for research
Goal/Achievemnet Orientation	Prioritizes learning and mastery goals such as improve skills or seek challenge	Frame the PhD as a chance to learn as much as I can, keep doing research or grow as a scientist even when tasks are difficult or slow.	Prioritizes performance goals such as to prove their ability or avoid looking incompetent	Frames lab work mainly as doing enough to look good, meeting the advsior's expectations, or just getting through to the degree, with emphasis on outcome and impression rather than learning
Effort Belief	See efforts or strategy as the path to mastery	Describe putting in time as necessary and worthwhile for becoming a better researcher, and expect that effort will pay off	See efforts as fruitless or evidence of low ability	Describe effort as a sign that someone isn't good at it, or suggest that extra work won't make a different because ability is already set.
Response to Challenge	Embrace challenges and willingly tackles hard tasks; persist in the fact of setbacks, seeks new strategies and reframes setbacks as information	When transition is rocky (such as hands off advisor, slow results, failed experiments), talk about figuring it out, adjusting strategies, asking for help, and eventually finding their footing rather than quitting	Avoids challenges to protect self image; Get defensive or give up easily, sees failure as diagnostic of low ability	Avoid demanding projects or methods, or abandon a direction quickly and explains it as proof they aren't capable or not good at certain kind of work
Response to Feedback/Criticism	Request concrete suggestion, learn from criticism	Describe asking advisors for specific comments, changing meeting frequency, or revising work in response to critical feedback, and saying that this made their work or interactions smoothers.	Ignore useful negative feedback, interpret criticism as judgement of ability	Descrive dreading meetings, feeling personally attacked by critique, or losing confidence and disengaging (such as avoiding the advisor, leaving a lab) because feedback is experienced as proof they are not good enough
Comparison/Success of others	Find lessons and inspiration in the success of others, models strategies	When labmates or other groups succeed, talks about learning from them, using their work to synergize with their own, or feeling motivated to improve	Feel threatened by the success of others	Respond to others' success by doubting their own work or withdraw rather than using others as models or inspirations.
Attributions for Outcomes	Interpreting failure as a temporary setback due to a lack of effective strategy or insufficient effort. Attribute problems to controllable, processable causes	Explain slow progress or mistakes in terms of things like inexperience, unclear expectations, or needing better strategies, and describe concrete changes they will make next time.	Statements attributing poor performance or setback to a stable, fixed flaw in the self, such as lacking innate talent or being "stupid"	Explain struggles by saying they aren't good at reserach, not smart enough, or not the type for this, with little reference to strategy, support, or context.