

Spotlighting Three Critical Themes from Computing Students in a Growth Mindset Program

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Abstract — This full research paper reports findings from a multitiered intervention focused on developing growth mindset among talented, low-income undergraduate students attending a College of Computing in the northeastern United States. Rooted in theories of intelligence, a growth mindset views intelligence and skills as being developed through persistent practice and learning from mistakes, while a fixed mindset sees skills as set at birth, never evolving, with mistakes becoming insurmountable barriers to success. The program in this study was designed to develop a community of learners with a shared framework for responding to academic challenges, to combat imposter syndrome, and to support persistence in their major and enter the workforce. During their first two years as college students, three undergraduate cohorts (totaling 32 participants) experienced four semesters of growth-mindset faculty mentoring concurrent with a community-building, growth mindset-focused seminar, and in their first year experienced two growth-mindset infused introductory programming courses. To address the research question, “How do talented, financially disadvantaged computing students understand growth and fixed mindsets?”, we report on qualitative data collected each semester, for each cohort. Focus group transcripts and individual written responses were thematically analyzed, drawing from a priori frameworks (social constructivism and self-efficacy in the context of mindset theory) and emergent codes to develop categories. Discussion is presented using frames of self-determination theory and positioning theory. We discuss the impact of these findings on students, implications for growth mindset interventions and provide guidance for using educational and developmental theories in the context of studies of growth mindset.

Keywords— *growth mindset, fixed mindset, communities of practice, self-determination theory, self-efficacy, positioning theory, computing education*

I. INTRODUCTION, BACKGROUND AND FRAMEWORK

This full research paper reports findings from a multi-tiered intervention focused on developing growth-mindset among talented, low-income undergraduate students attending a College of Computing at a private technical Carnegie-classified Doctoral University in the northeastern United States. The multifaceted program in this study was designed to develop a community of learners with a shared framework for responding to academic challenges, to combat imposter syndrome, and to support students to persist in the major and enter the workforce.

During their first two years as college students, three cohorts of undergraduate computing students (totaling 32 participants) experienced four semesters of a holistic approach that included (a) growth-mindset faculty mentoring running concurrently with (b) a community-building, growth mindset-focused seminar scheduled every two to four weeks, and (c) in their first year, two growth-mindset infused Introduction to Programming courses. In this context we investigated the guiding research question: “How do talented, financially disadvantaged computing students understand growth and fixed mindsets?” with the goal of informing computing education programs who seek to develop resilience and innovation in learners when confronted with struggles.

The concepts of growth and fixed mindsets stem from Carol Dweck’s foundational work that frames a growth mindset as the belief that mistakes, challenges, and setbacks are integral to learning and success [1], [2]. With a growth mindset, abilities are seen as malleable rather than fixed. This contrasts with a fixed mindset that is characterized by the idea that intelligence and talents are inherent, determined at birth and unchangeable. Those with a growth mindset are more likely to embrace obstacles as development opportunities and accept failures as part of the learning process rather than as barriers to success. A growth mindset also fosters resilience and persistence that aligns effort with achievement and views criticism as a means toward improvement rather than spotlighting deficiencies. Others’ successes are commonly seen as a source of insight and motivation rather than a threat to one’s own success [1], [3].

Conversely, a fixed mindset may lead to avoiding challenges out of fear of failure or being perceived as lacking ability. Obstacles are often viewed as roadblocks, and having to extend effort may be interpreted as a deficiency — especially when others appear to easily succeed. Feedback or constructive criticism can also be internalized as a deficiency, and comparing oneself to others’ achievements can lead to feelings of inadequacy, further manifesting as self-doubt or feelings of being a fraud, commonly known as imposter syndrome, and especially prevalent among individuals from minoritized backgrounds [4], [5], [6].

One approach toward fostering a growth mindset is shifting from person, or product-focused praise, to process-oriented praise. This means focusing on emphasizing strategies, efforts,

and perseverance as part of reaching a goal rather than innate personal traits or final project/activity outcomes. For example, rather than labeling a student as inherently ‘bad’ at programming, an instructor might instead ask, “How can I teach this material in a way that resonates with them?” This reframing helps establish adaptive approaches to future challenges and reinforces the value and processes of learning over innate ability that may be applicable to an isolated situation [3]. Applying a growth mindset opens the door for action in the face of adversity rather than deterministic inaction.

Recognizing that mindset development is shaped not only by individuals but also by those in their environment, our initiative aimed to address both student and faculty mindsets within a college setting. Supported by the National Science Foundation’s S-STEM program [7], we designed a two-year integrated intervention for 32 computing students — referred to as student scholars hereafter — over a four-year period. The first year was used for project planning and was followed in year 2 with cohort one as first-year students. In year 3 of the project, cohort two started as first-year students, while cohort one students were in their second year. In year 4 of the project, cohort three started as first years, while cohort two was in their second year. Each year’s cohort (10 students in cohort groups one and two; 12 students in cohort group three) engaged in two years of a multifaceted growth mindset initiative, including (a) structured faculty-student mentoring, (b) a dedicated student scholar seminar focused on developing and practicing a growth mindset, and, (c) curricular modifications to an introductory programming course sequence to incorporate growth mindset principles. Scholars were also supported with scholarship funding for their first two years alongside the holistic growth-mindset programming. Students’ financial need was the determining factor for qualification, alongside a holistic review of their application by admissions staff in consultation with project leadership. This two-year timeframe had been planned as part of the project proposal after considering attrition rates and patterns and identifying the first two years as a high-risk time for students.

Prior studies have explored student mindset, with research typically focused on a single, brief or isolated intervention [8,9] and near-term impacts. Even when the long-term effects are reported, as in Kim et al.’s study of growth mindset impacting college persistence and completion, the growth mindset intervention was again a very brief, isolated experience [10]. Our approach differed by embedding growth mindset interventions consistently over two years across the three facets of the student scholars’ experience: faculty mentoring, student scholar growth mindset seminar, and growth mindset-modified introductory programming course sequence. By collaborating with both faculty and students and emphasizing long-term development over innate traits or isolated achievements, students and faculty reframed setbacks as steppingstones to success. The interventions encouraged students to stretch beyond their comfort zones, to understand effort as a sign of growth potential, to welcome challenges, to reject the idea that intelligence is demonstrated solely by speed or perfection, and to internalize that practice and persistence can lead to expertise. In doing so, we developed a model aimed at reshaping

perceptions of learning and ability in meaningful, sustainable ways [1].

Scholars were paired with a faculty mentor based on personal background and professional technical interests. Regular meetings every two weeks over two years used a growth mindset approach for focusing on both personal and academic struggles. Faculty mentors had prepared for this by participating in a growth mindset community of practice to learn about a growth mindset approach and to hone their own mentoring skills [11]. Specific topics included considering effort as a means to achievement, avoiding risk as instantiating a fixed mindset, shifting our own mindset from fixed approaches to growth approaches, using feedback as a means to move forward (growth mindset) rather than becoming stifled by it (fixed mindset), normalizing mistakes, emphasizing the importance of process praise over product or personal praise and paying attention to self-talk in developing a more growth-oriented mindset [12].

Throughout their two-year growth-mindset programming, students also participated in a community-building, growth mindset-focused seminar scheduled every two to four weeks. The hour-long sessions focused on making meaning of growth and fixed mindset and actively practicing growth mindset. Short activities has scholars considering a time that they had seen a fixed mindset in themselves or another and how to reframe the situation with a growth mindset. Scholars also shared these examples with the group and discussed alternative ways to shift mindsets. Often, the examples served as a means to discussing their shared experiences, especially challenges they were facing and how they were managing them. Challenges were sometimes academic, specific to a course and/or assignment, and other times scholars shared about their challenges outside of academics like family and roommate issues, finding a campus job or working through the muddled waters of finding housing [13].

The two introductory programming classes instructional slides, assignments and activities were infused with growth mindset language and content. Process was emphasized over outcomes during instructional lessons and in the language in the assignments. Course augmentations also stressed the value of making mistakes and reading error messages as a way of normalizing mistakes and combating the imposter syndrome. As illustrated in the following quote,

“I think another helpful thing is since [the instructor] does live coding in front of us, sometimes they make mistakes and then we get to watch them troubleshoot and try to figure out, okay, why doesn't this work? Let's try and fix it. And just being able to watch somebody else debug their code helps you. At least it helped me a lot to understand, okay, I have an issue, let's see the first step of what I need to do to fix this.” (Cohort 1 Semester 1).

Zero syntax errors, using errors to make incremental progress, slowing down to understand and internally process the meaning of a prompt, building a reference glossary of errors and fixes, live classroom coding to demonstrate errors and the processes to resolve them, and discussion of problems typically experienced by novice programmers were intentionally woven into course materials [13].

In the following sections, we describe the findings from three cohorts of student scholars who were part of this holistic growth mindset experience across their first two years of academic study. In determining theoretical frameworks with which to analyze the data, we found overlaps between growth mindset and several applicable frameworks, such as motivational theories (i.e. self-determination theory [14], psychological theories of regulation and response to stress (i.e. dialectical behavioral therapy [15], and theories of development and learning (i.e. self-efficacy [16], and social constructivism [17]). These overlaps suggest that developing a growth mindset is not just about promoting perseverance or effort but also involves the process of learners' shifts in self-perception, interactions with others, and the engagement with the culture and community around them.

II. METHODS

To investigate the research question, “How do talented, financially disadvantaged computing students understand growth and fixed mindsets?”, we conducted a thematic analysis [18-22] of qualitative data collected from three cohorts of students (32 total students) each semester of their two-year program. As the three cohorts had staggered start dates, the data was collected over four years and represents twelve datasets. Participants provided written and verbal informed consent, and the data was drawn from both hour-long focus groups and individual written responses to the focus group questions. Focus group questions were developed using both a priori tenets of growth and fixed mindsets, and open-ended questions for a posteriori data collection. The focus group protocol was comprised of 12 questions, which were divided into a general section as well as sections for each programmatic component participants experienced. Students also completed a growth mindset assessment each semester, however those results are beyond the scope of this paper and forthcoming. Focus group sessions were conducted at the end of the first, second, third and fifth semester in the program while the individual responses to the focus group questions were collected in the fourth and sixth semester in the program, generating data from both the robust group discussions and from individual, anonymous reflections. This duality provided opportunities for all students to share both publicly and/or privately. The focus group protocol included, ‘How would you explain growth mindset and fixed mindset?’, ‘How would you describe the purpose of the program to someone else’ and ‘Can you give an example of when you exhibited a growth and fixed mindset this semester?’. Students were also asked to reflect on each of the program components: growth mindset faculty mentoring, the growth mindset-focused seminar, and the programming courses I and II which had been revised to infuse growth mindset principles into instruction. Focus group audio files were transcribed verbatim and together with the individual written responses were analyzed using a priori codes, from theoretical frameworks of social constructivism [17], e.g. change over time, learning through doing, and from self-efficacy [16], e.g. belief in self, predictive language. In addition, we coded for emergent codes using thematic analysis of the content of a given quote. Thematic analysis proceeded through three rounds of codebook refinement using investigator triangulation [18]. The theoretical frameworks of self-determination theory [14], self-efficacy [16],

and positioning theory [23] were utilized to contextualize the thematically generated final codes reported below. As space is limited, below we report the results of student understandings of growth mindset and, when included in the data, fixed mindset, with additional results being reported in other manuscripts [11-13].

III. RESULTS AND DISCUSSION

Three themes are reported below: Theme 1 - Characterizations of Growth Mindset, Theme 2 - Intersections Among Characterizations of Growth Mindset, and Theme 3 - Frequency of Each Characterization Across Four Semesters. Through analysis of student responses to the focus group question, “How would you describe a growth mindset?”, our findings indicated four characterizations in the responses: (a) growth mindset as *Self-efficacious Positive Stance*, (b) growth mindset as *Action Strategies*, (c) growth mindset as *Belief in One’s Potential, Expanding Perceived Limitations and Capabilities*, and (d) growth mindset as *Transformative, Liberatory with Change Over Time*. Each distinct code is described below, along with exemplar quotes. We also report below the frequency of each description of growth mindset across each of the four semesters of data collection and the intersections of the four descriptions. Discussion of each finding is reported with the results.

A. *Self-efficacious Positive Stance*

Students described growth mindset as enacting a positive reframing of negative events or thoughts to infuse ‘openness to possibility’ into the equation.

“I mean I want to add on, I think it's a lot about, it's growth mindset. So it's your mindset on things. I want to add on to what they said. It's a lot about thinking positively rather than ... pessimistic. Growth mindset I think is very optimistic, thinking that you can, you will or you could. Yeah.” (Cohort 2 Semester 1).

Whereas a positive outlook might accept the finality of a negative event/thought and introduce an equal but opposite positive thought as a counterweight, positivity in growth mindset reframes the interpretation of the negative event/thought oftentimes by introducing openness to possibility. For example, having a positive outlook might sound like, “I’m just not good at math, but I’m really good at writing”, whereas employing a growth mindset would reframe this statement as, “I’m not good at math yet, but I know I can improve”. Students in our study emphasized the positivity as focused on themselves or their experiences, e.g. diminishing negative self-talk or focused on a negative event. For example, *“Yeah. It's basically like having the hope of knowing that you'll be able to do something that you're not getting right in the moment. It's just more of a positive mindset rather than a negative”* (Cohort 1 Semester 2). This self-efficacious positive stance can occur through use of positive tone/language about and/or by adding openness, as opposed to finality to the meaning of the negative event/thought, *“It means regardless of what happens, instead of dialing on the negative parts of the situation try to see how a problem can benefit you in the long run.”* (Cohort 1 Semester). In the above examples students experienced a triggering event and reframed their interpretations applying a self-efficacious

positive stance perhaps to emotionally regulate towards feelings that then support next steps more in-line with the end goal [15], combating paralysis in the face of negative emotions.

B. Action Strategies

Students across all cohorts described growth mindset as utilizing ‘Action Strategies’. These actions represented different ways students could respond to challenges or barriers to their goals. Strategies were described as being used in tandem or sequentially. Excerpts were coded as ‘Action Strategies’ if they emphasized effort, taking action, being active in the solution to a problem, and changing strategies, e.g.,

“Well, it's like when you come across a situation it's not closing doors for yourself. It's just trying everything and anything really to that goal” (Cohort 1 Semester 1) and “A growth mindset is when a person is not fixed about an idea. For example, instead of being completely against something, even if you don't like it you're willing to try it again and change your mind about something” (Cohort 3 Semester 2).

C. Belief in One's Potential and Expanding Beyond Your Perceived Limitations/Capabilities

Students' conceptualizations of growth mindset increasingly included references to expanding their views of self, both in asserting that a growth mindset includes belief in your own abilities and/or that a growth mindset meant they could change their abilities, oftentimes without limit. An exemplar for the ‘Belief in One's Potential’ was,

“A fixed mindset is where you think ‘I can never do this ... This doesn't make sense and it never will,’ whereas a growth mindset is where you recognize that while something may be hard now or not make sense now doesn't mean that it will never make sense. It just means that it may take longer for you to understand it, but you will understand it.” (Cohort 1 Semester 4).

The ‘Belief in One's Potential’ coded excerpts were almost entirely future-oriented, as were the ‘Expanding Beyond Your Perceived Limitations/Capabilities’, but the latter included emphasis on specific capabilities or specific limitations as seen in the following example, “A growth mindset is one where you don't pigeonhole your abilities, and instead always think that you can do something, but you need to plan on how to properly do it” (Cohort 3 Semester 2). These findings represent continued development of self-efficacy [16], the timing of which is reported below.

D. Transformative, Liberatory, Change Over Time

One of the most interesting codes that developed from this data set was related to the transformative and liberatory change students experienced. The descriptions of transformation encompassed past to present and present to future. Descriptions usually encompassed either recognition of transformation, or the liberatory nature of developing and applying a growth mindset. Examples of growth-mindset descriptions that encompass a transformative, liberatory, change overtime were evident in each cohort, and even in early semesters; however, there seemed to be an increase of these kinds of descriptions, reported below in section III.F, at the end of the second and third semesters of the program. Below, we share an example of each of the

transformative descriptions of growth mindset and liberatory descriptions of growth mindset.

“A growth mindset means understanding that nothing is static, and that allowing myself to be dynamically oscillating is a natural life process and to not quit because of it” (Cohort 3 Semester 2).

“Yeah, I don't know, you talked about the stamina. I don't feel like growth mindset; you have a stamina with it. I feel like this is kind of the events, the Ls [losses]. The Ls start rolling in and it's the mindset that you have. The smaller Ls, you know can take it, but it's like when those big things come up, it just kind of disrupts your processing and stuff like that. And it's like you have to get to a point where you're not letting your emotions drive the bus, as you said. You got to get into a place mentally where you're not self-sabotaging yourself” (Cohort 1 Semester 3).

Transformative and liberatory language are integral signs of moving to a more self-determined, intrinsically driven motivation [14] rather than operating through extrinsic, often negatively driving motivations. Participants' sense of autonomy and competence, two of the three pillars of self-determination theory, are central to these transformative and liberatory descriptions of growth mindset, with relatedness, the third pillar, less evident in the data.

E. Intersections of ‘What is Growth Mindset?’ Codes

In 89% of the instances (134 of 150) when students defined a growth mindset, they utilized more than one descriptor. The most common paired codes were descriptions of growth mindset as ‘Belief in One's Potential and Expanding Beyond Your Perceived Limitations/Capabilities’ and as ‘Transformative, Liberatory, Change Over Time’. This combination suggests that increases in self-efficacy combined with a growing sense of competency could be transformative for students. In addition, the intersections were almost always in pairs, with only 10 of 150 excerpts exhibiting three-way intersections.

TABLE I. GROWTH MINDSET CODE INTERACTIONS

What is Growth Mindset? Interactions	Positive	Belief	Action	Transform	Sum	Avg
Self-efficacious Positive Stance	-	10	3	10	23	8
Belief in One's Potential and Expanding Your Perceived Limitations/ Capabilities	10	-	11	25	46	15
Action Strategies	3	11	-	8	22	7
Transformative, Liberatory, Change Over Time	10	25	8	-	43	14
Totals					134	34

TABLE II. GROWTH MINDSET CODES INTERSECTIONS AND EXEMPLARS

Intersection	Exemplar
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Transformative, Liberatory, Change Over Time AND Self-efficacious Positive Stance	<i>"It also means to be positive in the face of hardship to move past, instead of being fixed in place."</i> (Cohort 2 Semester 2)
Transformative, Liberatory, Change Over Time AND Action Strategies	<i>"Well, it's like as I said, if you met some people would be like 'this sucks' or something like that. It's like whenever I face a problem in something, I don't really get that kind of idea. It's more like I just straight go to, "Okay, this is interesting. How can I fix this? How can I get around this?" instead of just focusing on any shortcoming or something."</i> (Cohort 1 Semester 1)
Transformative, Liberatory, Change Over Time AND Belief in One's Potential and Expanding Beyond Your Perceived Limitations/Capabilities	<i>"I think for me it's understanding that what you think is the limit probably isn't. There's very little limits that we have. I guess it just depends on the consequences that you're willing to or not willing to face. But that for the most part. Setbacks don't mean that it's a permanent barrier and that. It's OK. It's probably better that you do fail like a lot because you can get too strict and too uptight and never experience what it's like to have it down, and then suddenly you face it down and you're stuck in it. So understanding how to just move past different scenarios."</i> (Cohort 3 Semester 1)
Belief in One's Potential and Expanding Beyond Your Perceived Limitations/Capabilities AND Self-efficacious Positive Stance	<i>"A growth mindset means to be optimistic and to not think that you can't do something. It's to have hope and believe that you are capable of achieving a goal no matter how difficult."</i> (Cohort 2 Semester 2)
Belief in One's Potential and Expanding Beyond Your Perceived Limitations/Capabilities X Action Strategies	<i>"A growth mindset for me means not giving up and keep trying even after failed attempts with the thought you know will make it through to your goal."</i> (Cohort 3 Semester 2)
Self-efficacious Positive Stance X Action Strategies	<i>"I would say that means thinking that even if you can't do it right now you know that you'll eventually get to a point where you can do it and you know the steps that you might have to take to get there, but never having the mindset of thinking like, okay, I'm never going to be able to do this. I should just give up now. You always know to keep trying."</i> (Cohort 1 Semester 1)

F. Analysis of Frequency

Each code for 'What is growth mindset?' was analyzed for frequency across each semester (S1, S2, S3, S4). A peak in the quantity of descriptions of growth mindset in response to the focus group question occurred mid-program, during the 3rd and sometimes 2nd semester. While statistical significance was not tested as part of this qualitative study, the largest and most noteworthy increase was a doubling of instances of students describing growth mindset as a 'Belief in One's Potential and Expanding Beyond Your Perceived Limitations/Capabilities' after the first semester. Interestingly, students' description of growth mindset as a 'Self-efficacious Positive Stance' remained relatively stable across the semesters. Considering the qualitative responses presented above, this expansion from thinking positively to belief centered on self, paired with actions that the self can take, could indicate an integration of growth mindset principles into the individual rather than an individual having just an awareness of growth mindset. Additional analysis comparing positive thinking indicators could yield additional insights.

TABLE III. GROWTH MINDSET CODE FREQUENCY ACROSS SEMESTERS

What is Growth Mindset?	S1	S2	S3	S4	Sum	Avg
Self-efficacious Positive Stance	5	7	5	5	22	6
Belief in One's Potential and Expanding Your Perceived Limitations/Capabilities	8	19	16	16	59	15
Action Strategies	7	4	10	12	33	8
Transformative, Liberatory, Change Over Time	4	9	14	9	36	9
Totals	24	39	45	42	150	38

IV. IMPLICATIONS AND LIMITATIONS

The above findings can be used to inform STEM departments, programs and faculty who are working to develop resilience, intrinsic motivation and cognitive flexibility among students who are struggling. The descriptions of growth mindset throughout the four semesters of our program point to continuing development from both internal and external events. The shifts in language, some descriptions indicating 'you' versus others indicating 'I' potentially indicate a shift in internalization. These data paired with the increase in descriptions of 'belief in self' and 'transformation or liberation' could also potentially indicate additional integration in self rather than just more superficial repeating of accepted definitions of growth mindset. However, it would appear from the data that a steadier state occurs after the third semester of the intervention. Li and Bates contradicted the effect of mindset on initial grades, grade change over time, higher cognitive ability scores, resilience to failure as measured in subsequent performance [24]. Other studies [8,9] have also presented limited support for the effect of mindset in student success.

However, these studies differ significantly from the work conducted in our study in that mindset interventions were singular, extremely limited in nature or non-existent at all. Methods used were quantitative rather than qualitative, with mindset surveys serving as a ‘snapshot’ of a momentary state of mind during an experiment rather than robust, detailed descriptions of change over time in the participants’ own words. Using mindset as a predictor of initial grades raises questions beyond the scope of this paper, yet worthy of consideration. For example, mindset theory does not dismiss natural ability, and as such, why would it be used as a predictor for grades without first understanding a baseline cognitive ability? Our work differed significantly from these noted studies in that students participated in a multifaceted approach to growth mindset over a two-year period, whereby they were enrolled in introductory computer programming courses infused with growth mindset approaches, they were mentored by faculty with a growth-mindset approach and they participated in a community-building, growth mindset-focused seminar scheduled every two to four weeks. Thus, the findings presented in this work present an opportunity for future analysis of integration into self at both a particular moment in time and over time, as students are progressing throughout their academics.

A. Mapping Reported Codes to Growth Mindset Principles

The findings presented here do not map cleanly onto the tenets of growth mindset as described by Dweck (1). The contours of growth mindset include first and foremost a belief that one’s intelligence and abilities can change. This belief is characterized by ‘embracing challenges’, ‘persisting in the face of setbacks’, ‘seeing effort as the path to mastery’, ‘learning from criticism’, and ‘finding lessons and inspiration in the success of others’. The code from this study, taking a *Self-efficacious Positive Stance*, maps onto the central tenet of growth mindset, ‘belief in one’s intelligence and abilities to change’ and could also map onto “positive effort beliefs” associated with ‘seeing effort as the path to mastery’ [25] and ‘persisting in the face of setbacks’. However, taking a self-efficacious positive stance is not a solid fit for any one particular dimension of Dweck’s growth mindset. Similarly, *Transformative, Liberatory, Change Over Time* as a code maps onto the central tenet and perhaps ‘embracing challenges’, but not directly to one particular tenet. Student scholars’ description of growth mindset as *Action Strategies* would partially map to ‘seeing effort as the path to mastery’ and ‘persisting in the face of setbacks’. Lastly, *Belief in One’s Potential and Expanding Beyond Your Perceived Limitations/Capabilities* map to the central tenet, to ‘embracing challenges’ and ‘persisting in the face of setbacks’, however this emergent code captures more the internal world related to how student scholars observed change in themselves. Student scholars’ definitions of growth mindset were drawn not only from their application of growth mindset but described outcomes they experienced holistically. If the coding process had proceeded with a priori codes alone, there is a risk of missing the complexity of this internal world that provides robust and possibly more powerful evidence of impact.

B. Future Utilizations of Positioning Theory as an Analytical Framework

Given the multitiered interventions of this program, including a very strong mentoring component, we propose that positioning theory [23] better captures the discursive processes, such as language use, social interactions, and self-narration, through which students actively position themselves and are positioned by others as capable, resilient, or limited. As a result of highlighting the storylines and speech that shape mindset discourse, this approach provides deeper insight into students’ evolving beliefs about growth mindset and personal development. With this in mind we suggest that positioning theory could serve as a theoretical framework for future analyses of internalization of growth mindset.

Drawing on positioning theory [23], we can understand these utterances as more than just descriptions — they are speech acts that actively construct the speaker’s identity in a given moment. Throughout the dataset, students consistently used emotionally affirming and agentic language, including phrases like “*keep trying*,” “*you can be proud of yourself*,” and “*you can see that less as a drawback and more as something that only helps you push forward*.” A growth mindset expression enacts a learner identity that embraces challenge, expects growth, and normalizes failure. The language students used in this way often positioned themselves as resilient and capable, in contrast to earlier moments of self-doubt or fixed mindset thinking. As a result, they aligned themselves with modern narratives of perseverance and self-discipline, and also became active agents in their own development, rather than passive recipients of feedback.

A growth mindset was often internalized not only after or during moments of reflection, but also by how students spoke about themselves. Therefore, through this speech used during focus groups and open response survey questions, students demonstrated how they constructed a growth mindset through meaning-making [15, 16, 17]. When students say “*you will eventually get it*” or “*you have to prove to yourself that you can do it*,” they were not simply reciting a learned framework, but performing a learner identity that values growth, consistency, and future possibility. These coaching-like statements could be an early precursor to full internalization.

In the framework of positioning theory, storylines provide the broader cultural and situational contexts within which students construct meaning, position themselves, and interpret their experiences. When applied to the development of growth mindset, storylines reveal how students come to understand and internalize mindset beliefs not merely through direct instruction, but through narrative shifts that unfold in response to academic and emotional challenges. Many students in the data did not articulate a growth mindset as an immediate or stable belief. Instead, their narratives often reflected a transition from fixed to growth-oriented thinking, typically catalyzed by a moment of struggle, failure, or reflection. These shifts are embedded in storylines that draw from cultural narratives of perseverance, resilience, and self-improvement. For example, a student who describes “*rebounding after hitting rock bottom*” or “*building a plan to get back on track*” is positioning themselves within a storyline that emphasizes effort, agency, and emotional regulation in the face of adversity. Importantly, these storylines were situationally anchored—students described their mindset not as abstract ideology but as something enacted in context:

during late-night coding errors, academic probation, physical recovery, or time management breakdowns.

Using this approach would further reveal hidden narratives that shape students' understanding of growth mindset through the discursive processes they use to explain it. As a result, a deeper understanding of student positioning could inform more responsive, equitable, and effective educational practices at all levels, from classroom interventions to institutional policy-making. Firstly, in this study, results suggest that growth mindset interventions may be effective when they are framed and reframed as narrative tools rather than one-time lessons over time. Thus, educators and mentors might provide students with the opportunity to re-narrate their academic setbacks as moments within a broader, evolving story. A student might be asked to reflect on what has changed in their thinking during a seminar session, a classroom discussion, or assignment preparation. In helping students articulate these narrative shifts, educators enable them to reposition themselves as active learners adopting a growth mindset. Second, the analysis of language use and speech acts in the data highlighted how growth mindset is often internalized through affirmative and self-authoring language. Educators and support staff can amplify this by modeling growth-oriented language, providing feedback that reinforces student agency, and encouraging peer-to-peer dialogue that normalizes struggle as a meaningful part of learning. Faculty development efforts could incorporate training in how to linguistically position students through encouraging feedback, rhetorical framing, and affective validation. Third, positioning theory can help explore the contextual and social construction components of growth mindset development. This is particularly salient given the cohort nature of the program. We are interested in exploring and reporting to the engineering and computing community insights and additional lessons-learned from a more systematically delivered intervention. From the data above, we believe a closer look at classroom norms, institutional messages, and mentoring relationships is warranted, in this program and in others as they shape students' developing narrative contexts. When students hear growth mindset language only in isolated workshops, but encounter fixed mindset cues in grading systems, competitive environments, or dismissive interactions, their ability to maintain a growth-oriented identity may be compromised. Findings from this work suggest that integrating consistent storylines of growth and self-efficacy into faculty, peer mentoring, advising, and support services could be a more effective approach.

C. Limitations

Focus groups were audio recorded and not video recorded; as such, individual students' responses cannot be tracked over time for change at the level of the individual. Therefore, focus group responses are considered representative of the cohort at a particular point in time. This effect is mitigated in part by offering the focus group as a survey, not only alleviating the data collection fatigue and the challenge of scheduling but also providing a chance for students to share privately or publicly. Timing of the focus groups was intentionally at the end of each semester of the program, however, a robust focus group prior to beginning the program would have given additional insight into students' mindset at entry into the program. A growth mindset

inventory using Likert-type questions was administered to students at the start of the program and then at each end of semester. Select questions or potentially a composite growth mindset score could be developed for each cohort and might provide some context for the qualitative analysis presented above. Future analysis should investigate whether changes in the content of the descriptions, timing and interactions are consistent across all three cohorts. Additionally, a brief survey with Likert-type questions could be developed using the four descriptions of growth mindset reported above and administered to future cohorts at the start of every semester. Such a survey would bolster any statistical analyses that were conducted. Lastly, the results presented in this paper provide a description of growth mindset built from student scholars' understanding after two years of holistic growth mindset interventions, providing a foundation on which to situate results beyond the scope of this paper.

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