Examining Engineering Students' Shift in Mindsets Over the Course of a Semester: A Longitudinal Study

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Abstract

Students, like all people, have elements of both growth and fixed mindsets. We studied shifts in both types of student mindsets over three one-semester courses. We found no significant change in students' growth mindset at the beginning of the semester compared to the end of the semester. However, students' fixed mindsets showed a statistically significant increase of 0.37-points from the beginning of the semester to the end of the semester, with an effect size of 0.43. Two multilevel models were used to understand why students' fixed mindsets may have increased 1) personal sources—mastery goal, performance goal, and internal recognition, and 2) situational sources—classroom goal orientations and external recognition. The analyses were conducted using pre-and-post survey responses of 38 students at a Hispanic-Serving Institution. Students' endorsement of a performance goal orientation, which focuses on demonstrating competence and managing others' perception of their abilities, increased their fixed mindset views at the end of the semester. In the model focused on situational sources, we found that students' fixed mindset increased when they perceived their classroom environment endorsed a performance-approach goal structure and by receiving external recognition. When comparing both models, students' fixed mindset increase was largely explained by classroom environmental sources. Specifically, students' fixed mindsets increased when they perceived that their classroom environment valued a demonstration of competence (i.e., classroom performance-approach). Being recognized as an engineer by peers and instructors also increased students' fixed views of their abilities. Conversely, one situational source was found to decrease students' fixed mindset views, i.e., a classroom environment that promotes mastery goals. Our study points to an apparent and crucial role engineering classroom environments have in promoting certain mindsets. The study concludes with one pedagogical strategy that may help mitigate the inadvertent promotion of a fixed mindset, e.g., a mastery learning pedagogical intervention.

Introduction

Background

Students' beliefs about their capabilities for intellectual growth and development can be understood as their mindsets. Dweck theorized [1], [2] there are two types of mindsets: *growth mindset*, which is the belief that abilities can be developed or grow over time and *fixed mindset*, which is the belief in a natural ability or have a certain amount of ability that cannot be changed. People with a growth mindset will accept constructive criticism, challenges and persevere when faced with setbacks. However, individuals with a fixed mindset will show the opposite. Students with a fixed mindset might be reticent to attempt challenging tasks. Fixed mindset students have the attitude that their flaws result in failures, and they may feel vulnerable if their flaws are in danger of being unmasked [1], [2] Dweck and her colleague [3] showed that people with a fixed mindset were likelier to demonstrate a helpless response to challenges, while those with a growth mindset welcome challenges.

Fixed and growth mindsets are typically juxtaposed, creating a belief that you either fall under one camp or the other. Yet, Dweck [1] has affirmed that an individual can have a combination of both fixed and growth mindsets depending on the context, and that "all of us have elements of both- we're *all* a mixture of fixed and growth mindsets," and they can be changed over time [p. 47]. For example, some engineering students may exhibit a fixed view of their ability to learn organic chemistry concepts. Yet in another domain, such as calculus, they may endorse a more incremental view of their abilities that manifest as a growth mindset. Even within the same domain (i.e., a statics course), students may exhibit elements of a growth mindset in one topic area, but fixed views of their abilities in another. The types of mindset students endorse have implications for how they view and respond to challenging tasks, their persistence in a difficult engineering class, and their motivation to pursue engineering [1], [4]. Situational factors, such as feeling threatened or facing a challenge, can provoke an individual to take on a certain mindset [5].

There are linkages between students' growth mindset and various success measures. For example, studies of elementary and secondary students show that a growth mindset is associated with better academic achievement and lower stress levels [2], [4], [6]. Adolescents with a fixed mindset may believe they need to work hard because they're not smart, are more afraid of failure, or fear making mistakes. Compared to a growth mindset, fixed mindsets predicted greater reports of greater psychosocial stress [7]. High school students from Chile who maintained a growth mindset were much more successful in overcoming the adverse effects of poverty on their academic achievement than those who exhibited a fixed mindset [8]. When considering studies on mindset in engineering-related domains, one study found that elementary students' growth mindset was a strong predictor of their performance in an assessment after an engineering-related learning unit [9].

More recently, several studies have used growth mindset interventions on undergraduate engineering students; however, the studies have produced mixed to null effects. Rhee and Johnson's [10] longitudinal study examining the impact of a growth mindset intervention found no significant difference in academic performance or retention among women, minoritized students, or Pell-eligible students. Frary [11], who implemented various growth mindset-related activities throughout the semester in her Thermodynamics of Materials course, found that students described their approach to learning through the lens of a growth mindset at the end of the semester, which was a shift from their beginning semester responses. Responses from a battery of survey questions using a fixed and growth mindset scale showed that students' post-survey responses trended higher for growth mindset at the end of the semester than those at the beginning [11].

Other studies seeking to understand undergraduate engineering students' mindsets have also reported interesting yet conflicting results. Reid and Ferguson's [12] study found that while first-year engineering students' fixed and growth mindsets did not significantly change from the beginning to the end of the semester, these engineering students had substantially greater fixed and growth mindset scores compared to a group of business students. Another study found that Black and Latinx engineering students reported lower levels of growth mindsets than their White peers, yet they also reported lower levels of fixed mindsets [13]. Said differently, Ge et al.'s [13] cross-sectional study showed that White engineering students demonstrate a higher predisposition towards a growth mindset and a higher predisposition towards endorsing a fixed view of their abilities. An exploratory study aimed at understanding the relationship between students' engineering identity and mindsets longitudinally found that both a fixed and a growth mindset were positive predictors of identity [14]. However, the authors did acknowledge that there may be moderating effects not considered in the model, such as course difficulty, that may also help explain the positive relationships [14]. The studies mentioned above further support Dweck's claim that people can endorse both a fixed and growth mindset. Yet, there remains a gap in the literature regarding the factors influencing a fixed versus growth mindset among engineering students. Specifically, it is unclear what drives engineering students' adoption of a fixed view of their abilities as opposed to a belief in the malleability and potential for the growth of their cognitive capabilities.

Purpose

This study examined *if* and, most importantly, *how* a group of undergraduate engineering students' mindsets changed over the course of a semester. Dweck and colleagues' [15], [16] early work asserted that those who believe intelligence is malleable and can be developed over time (i.e., growth mindset) were more likely to adopt mastery goals. Conversely, individuals with a fixed view of intelligence were more likely to endorse performance goals [15], [17]. Mastery and performance goals underlie achievement goal theory, a prominent motivational theory. Therefore, we use these goal orientations as possible explanatory factors to help us understand students' mindsets shifts over a semester. We incrementally examine the following research questions:

1) Do students' fixed and growth mindsets shift from the beginning to the end of the semester in three gateway engineering courses?
2) What motivational sources help explain students' mindset shifts over the course of a semester?

Theoretical Frameworks

Achievement Goal Theory

When students are faced with academic challenges, what motivates their response? Why do some students demonstrate academic resilience while others demonstrate helplessness behaviors? While Dweck's more recent work would rationalize that students' academic resilience and motivation to respond to a challenging task can be attributed to their mindset [1], [2], [5], we believe there is also a linkage between students' mindsets and the type of goals students endorse. Achievement Goal Theory (AGT) offers an explanation for understanding how students respond to such challenges. The early rendition of AGT emphasized that students respond through two types of goals: mastery goals and performance goals [18]. AGT focused on why students try to achieve a particular goal and less on the goal itself. The type of goal orientation students adopt has implications for adaptive or maladaptive behaviors, outlooks, or reactions students subsequently embrace in the face of setbacks [19].

This study focuses on two types of personal goal orientations: mastery and performance goals, and two types of classroom goal structures: classroom mastery and classroom performance. Early literature on achievement goal theory identified classroom settings as a situational constraint that elicits particular patterns of motivation [20]. Therefore, the inclusion of classroom goal structures in our discussion of achievement goal theory is pertinent as they also help elicit patterns of motivations that are situation specific.

Students who endorse a mastery goal orientation embrace a mindset of developing, improving, mastering new knowledge. Mastery goals are typically endorsed by students who view their intelligence as malleable, a characteristic of a growth mindset. They tend to see challenges as opportunities for growth, view mistakes as learning experiences, and tend to be more resilient in the face of setbacks [15]–[17], [19]–[21]. A systematic review documenting the effects of having a mastery goal orientation found that endorsing this goal leads to with greater motivation, deeper learning, and higher achievement in a variety of domains [17].

Performance goal orientation are focus on achieving a good outcome, such as high grades. Students with a performance goal orientation are motivated by ego, external rewards, and strive to demonstrate their abilities to others [15]–[17], [19]–[21]. Students who endorse a performance goal orientation tend to compare their performance relative to that of their peers. Dweck's [15] work demonstrates that a person with a performance goal orientation will more likely endorse a fixed mindset, where they view their abilities as innate and unchangeable. Yet research has shown mixed results among students who adopt a performance goal orientation. Some studies concluded that a performance-approach lead to adverse outcomes such as cheating, giving up in the face of difficulties, and diminished interest in learning, while other studies concluded that performance goals lead to higher engagement in tasks that interest students (see [17], [21] for a cogent synthesis). In one study of engineering students enrolled in a Statics course, performance goal was the only achievement goal orientation that predicted overall class performance, which included exam grades and assignments [22].

The original narrative on achievement goal theory positioned mastery goals as the protagonist and performance goals as the antagonist [21]. Harackiewicz and colleagues [23] study led to a reconceptualization of goal theory that countered the protagonist-antagonist dualism. A fundamental argument for challenging the dualistic view of mastery and performance goals is that performance is a gateway for students' future opportunities and academic progression [21]. AGT evolved to embrace the idea that students can pursue both mastery and performance goals and, under certain conditions, both goals can produce beneficial educational outcomes [23], [24], albeit this theory is yet to be proven with undergraduate engineering students. We acknowledge that there is a camp within the AGT scholarship that advocates for Elliot and McGregar's [25] inclusion of avoidance as a second dimension to mastery and performance goals (e.g., performance goal and performance-avoidance goal). However, we do not include these dimensions in our description, analysis, or discussion as studies suggests that the high correlation between performance and performance avoidance creates statistical suppression [26], an effect we've observed in our dataset (correlation $r = 0.71$).

While achievement goal theory has been widely used across multiple disciplines and has withstood the test of time through its four decades of use, few studies have examined engineering students' achievement goal orientations or the effect these orientations have on mindsets. Additionally, recent publications continue to scrutinize the lack of motivation literature focused on racialized experiences of minoritized students [27], [28]. Our study extends the application of achievement goal theory using a sample of engineering students who identify predominantly as Latinx and are first-generation college students to understand how it informs changes in their mindsets.

Self-Representational Motive: External Recognition

In addition to understanding how students' goal orientations inform their mindsets, we were also interested in understanding how the act of being recognized as an engineer by external people changed students' fixed mindsets. Recognition can be thought of as a motivational source, not an achievement motive but as a self-presentational motive. A self-representational motive refers to the drive or desire to present a positive image of oneself to others. This refers to a person's need to maintain or enhance their self-esteem and social standing by portraying a favorable image of themselves [29]. Students who drive to outdo their peers, may also be tapping into a self-presentational motivation, potentially influencing their perception of their abilities (i.e., mindset) and, in turn, may also influence the type of goal endorsed [18]. While self-representational motives are considered separate from achievement goals, they still color students' motivational pursuits and can shed light on how their mindsets may be shaped. Therefore, we use external recognition, conceptualized as a self-representational motive to understand its effect on students' mindsets.

Method

Institution and Department Context

The institution is considered a Hispanic-Serving Institution in the Southwest with a very high enrollment of students who identify as Latinx. Specifically, the student body at the College of Engineering is 67% Latinx, 16% Asian-American, 4% Black/African-American, 5% white, and 3% unknown or multi-racial; 6% are international (including undocumented students), and 16% are female. Fifty-four percent of the students are first-generation, and 58% are low-income; only 20% have a parent who earned a bachelor's degree. There is also a large body of transfer students in the College of Engineering; some may have been in the sophomore class sections under study if they did not complete these courses before transferring.

Across the state of California, this institution awards the highest percentage of engineering degrees to Latinx students. One of the key missions, where intentional efforts have been placed, is to strive to be Hispanic-serving [30] rather than simply Hispanic-enrolling. Efforts made in building sustainable student success programs in the College, investment in increased course sections by the University, and an overall emphasis on student success has resulted in improvements to the four-year and six-year graduation rates. However, there remains concerns about low course pass rates in engineering courses, particularly in the sophomore-level gateway courses, and anecdotal concerns about the lack of student preparation for follow-up courses. In an effort to support our students, several engineering instructors adopted a new pedagogical approach, i.e., Mastery-Based Grading, which stems from mastery learning [31]–[34] and is aimed at allowing students more control over their course experience. With some early success and improvement in pass rates in such courses, a formalized faculty development program was created to more deeply develop this type of pedagogy and to conduct research into both the student and the faculty experience in mastery-based grading courses. One of the courses in the present study (Spring 2022) included pilot efforts in Mastery-Based Grading, but had not yet benefited from a formalized, structured faculty learning community which was officially launched in Fall 2022. Therefore, the results presented in this study should be thought of as baseline findings from students enrolled in courses where faculty members have not yet benefited from the formal Mastery-Based Grading training program or learning community.

Data for the Present Study

Data came from a study of three sophomore-level engineering courses (i.e., Statics, Strength of Materials, and Embedded Systems Programming I). Surveys were administered in seven course sections, with seven different instructors, at the beginning and end of the Spring 2022 semester; thus, the variables collected are longitudinal. Across the three courses, only 38 students completed both surveys. Student participation was a struggle this semester, despite offering each student a $15 Amazon gift card per survey completed, we were only able to accrue a small sample size.

Among the students who completed both pre-and post-surveys, twenty-four were enrolled in courses that were considered non- Mastery-Based Grading and fourteen were enrolled in courses that were implementing a pilot version of Mastery-Based Grading. Table 1 provides a summary of students' demographics. Students were given the opportunity to *mark all that apply* for their race/ethnicity classification; the race/ethnicity count will exceed the total number for each column. Since they are not mutually exclusive categories, we do not provide their percentages. The majority of participants in our sample identify as Latinx, and as such the sample of engineering students in this study are also predominantly Latinx. Similarly, the majority of the participants (71%) identified as first-generation college students, defined as neither parent having a bachelor's degree. The percentage of female survey responders (24%) was higher than the population of women in the College (16%).

Table 1
Demographics of Engineering Students Spring 2022 (baseline data)

	Total
Women	9 (24%)
Men+	26 (68%)
Race/Ethnicity++	
Asian	11
Black or African American	0
Latina or Hispanic	23
Middle Eastern	1
Native African	0
Native Hawaiian or Other Pacific Islander	1
Native American or Alaska Native	0
White	4
Another race/ethnicity not listed above	1
Parents' Level of Education	
First-generation college students	27 (71%)
Continuing-generation college students	11 (29%)

Note. +One student also specified they were cisgender.
++Students were allowed to select all that apply for their race/ethnicity therefore the sample size will appear higher.

Survey Scales

Mindset scales. The growth and fixed mindset scale developed by Dweck [1], [5] were used. Five survey items were used to create a composite score for growth mindset. Students were asked to rate the extent to which they agreed or disagreed with the statements using a seven-point anchored numeric scale from strongly disagree (0) to strongly agree (6). An example of a survey item used to create the growth mindset variable included, "You can change even your basic intelligence level considerably." Similarly, five different survey items were used to create the composite score for fixed mindset, for example: "You are a certain kind of person, and there is not much that can be done to really change that."

Achievement Goal Orientation. Five survey items were used to create the composite score for mastery goal orientation and three items were used to create the composite score for performance goal orientation. All achievement goal orientation items used were borrowed from the Patterns of Adaptive Learning Scales (PALS; [35]). Students were asked to rate how true they felt the statements were about themselves using a seven-point anchored numeric scale from not at all true (0) to very true (6). An example of a survey item used to create the mastery goal orientation variable included: “One of my goals is to master a lot of new skills for this course.” A survey item used to create the performance goal orientation variable included: “One of my goals is to look smart in comparison to the other students in my class.”

Classroom Goal Structure. Four survey items were used to create the composite score for classroom mastery. The items used were borrowed from the Patterns of Adaptive Learning Scales (PALS; [35]). Students were asked to rate how true they felt the statements were about their current course using a seven-point anchored numeric scale from not at all true (0) to very much so (6). An example of a survey item used was, “In this course, it’s OK to make mistakes as long as you are learning.” Lastly, two survey items were used to create the composite score for the classroom performance-approach construct. The items used were borrowed from PALS and they include: “In this course, getting good grades is the main goal” and “In this course, getting right answers is very important.”

External Recognition. The scale used for internal recognition and external recognition were borrowed the engineering identity scale [36]. Students were asked to rate the extent to which they agreed or disagreed with the statements using a seven-point anchored numeric scale from strongly disagree (0) to strongly agree (6). The composite score for external recognition included the following survey items: “My instructors see me as an engineer” and “My parents see me as an engineer.”

Data Analysis Procedure

First, all constructs used in the analyses demonstrated reliable internal consistency, that is, a Cronbach alpha range between 0.72 to 0.91 [37]. Two different types of analyses were conducted to answer our research questions. We used pairwise sample t-test to answer the first research question and multilevel modeling to answer the second research question. Normality was examined by calculating the skewness and kurtosis z-scores for each variable and compared against the range for small sample sizes i.e., ± 1.96 [38], [39].

To answer the first research question, we used a pairwise t-test to examine if the differences in mean scores for growth and fixed mindsets were statistically significant. For a pairwise t-test, additional assumptions of normality for the time 0 and time 1 mean difference scores needs to be examined. Through a Shapiro-Wilk’s test, it was determined that the pre-and-post difference scores for the fixed and growth mindset variables were normally distributed, $p = .236$ and $p = .227$, respectively, which adds a layer of validity to the results. An examination of the boxplots for each variable helped us determine there was no evidence of outliers. Any significant mean differences observed in the pairwise t-test were followed-up with a multilevel model to examine relationships that help explain the observed changes in students’ mindsets.

To answer the second research question, we used multilevel modeling, which is an extension of ordinary least squares regression that considers the nested structure of data such as longitudinal data. Our data are longitudinal because they were collected at two points in time, i.e., beginning of the semester (time 0) and end of the semester for the same participants (time 1). The nested structure of our data is such that time, at Level 1, is nested within participant’s repeated observations at Level 2 and allows us to account for variation within-and-between participants. The interclass correlation (ICC) value, which allows us to numerically estimate the proportion of fixed mindset variation due to between-student mean differences over time was 71%, while within-student mean differences over time (i.e., time-specific deviations about one's usual mean level) was 29%. We would like to point out that while, in theory there is the possibility to add a 3rd-level to include the course type, in practice, the sample size does not allow modeling a 3rd-level. Two multilevel models were examined separately to examine personal motivating sources and situational motivating sources separately. Given the modest sample size, it was not possible to combine both models into one. Additionally, separating the two types of achievement goals (i.e., personal and situational goals) mitigates multicollinearity issues caused when variables are highly correlated with each other.

To examine outliers, we used Mahalanobis distance which calculates how far an observed variable is from the center of the distribution, and we detected no outliers in the dataset. To evaluate the adequacy of the final models, we examined normality, homogeneity of variance, and homoscedasticity, and all were found to be acceptable. A post-hoc power analysis was conducted to ensure the sample size was adequate to detect differences or coefficient estimates, for all results that were statistically significant. The post-hoc power analysis for the pairwise t-test was conducted using G*Power software version 3.1, using a significance criteria alpha value of 0.05 and power level of 0.80 [40]. A different post-hoc power analysis using Monte Carlo simulation in Mplus (version 8.7) was conducted to understand if the results from the multilevel model had sufficient power. We found that a sample size of 38 participants, per time point, was sufficient enough to obtain statistical power at the recommended 0.80 level ($\alpha = 0.05$) for the significant results found in the model (i.e., Tables 3 and 4). The pairwise t-test and multilevel model were conducted using R programming language and statistical software system version 3.5.3 [41].

Results

RQ.1: Engineering students' mindsets shift by the conclusion of the semester

Using pre-and-post survey responses of the students we sampled, we examined whether they showed a fixed or growth mindset shift at the conclusion of the semester. Table 2 provides an overall summary of the results for both mindsets. We found no evidence that their growth mindsets significantly increased or decreased by the end of the semester, $t(37) = 1.02$, $p = .842$. Students entered their respective courses with above average growth mindset perceptions ($M = 4.34$, $SD = 1.04$), and although there was a slight decrease in average score, the decrease was not statistically significant ($M = 4.21$, $SD = 1.14$). Conversely, we found that students started the semester with low fixed mindset perceptions ($M = 2.12$, $SD = 1.16$), yet at the conclusion of the semester they demonstrated a statistically significant 0.37-point increase in fixed mindset, $t(37) = -2.63$, $p < .006$, with a small Cohen's d effect size of 0.43. Since our sample size was small (n = 38), we conducted a post-hoc power analysis to ensure there was enough power to confidently detect the small effect size. Given the results of our analysis we can conclude that the sample size was sufficient to detect an effect size of 0.43. To further understand the reason why students in our sample had an increase in fixed mindset views at the conclusion of the semester, we examined two potential sources, categorized as personal and situational motivational sources.

Table 2
Summary at Beginning and End of Semester Response Mean Values

	Mean (M), Std. Dev. (SD)	**Change (MΔ)**	**Significance**	**Cohen's D**
Growth Mindset	Beginning: *M* = 4.34, *SD* = 1.04	-	*t*(37) = 1.02, *p* = .842	-
	End: *M* = *4.21*, *SD* = 1.14			
Fixed Mindset	Beginning: *M* = 2.12, *SD* = 1.16	↑ 0.37	*t*(37) = -2.63, *p* = .006	0.43
	End: *M* = 2.49, *SD* = 1.27			

RQ2: Explaining students' change in fixed mindset over the course of a semester
To help explain why or how the fixed mindset views changed over the course of a semester for the students we sampled, we used achievement goal theory, a prominent motivational theory. Specifically, we considered personal motivating sources (e.g., mastery goal orientation; Table 3) and situational motivating sources (e.g., classroom mastery goal structure; Table 4). In both models, we included final grade and course type as control variables. For the students in our sample, their final grade did not have an impact on changes in their fixed mindset endorsement. Neither the specific course students were enrolled in (i.e., Statics, Strength of Materials, or Embedded Systems Programming I), nor the corresponding course instructor had an impact on students' changes in their fixed mindset views. Additionally, we can also conclude that the pilot version of Mastery-Based Grading implemented only in the Embedded Systems course, did not seem to have an impact on students fixed mindset changes when compared to students in the Statics course.

Personal motivational sources (Table 3).
First, the average fixed mindset views across students at the beginning of the semester (time 0) was 2.58 without considering other variables. Over the course of the semester, students' fixed mindset views increased at a rate of 0.35, p = .006. The variables classified as internal sources used in this model (i.e., mastery goal, and performance goal) are time-varying predictors which means we collected these variables over time. When considering internal motivational sources that explained why students fixed mindset may have increased, we found only one source. Specifically, students' fixed mindset views over the course of a semester would be expected to increase by 0.25, p = .002 as a result of endorsing performance based-goals. No other internal source had an influence on students' fixed mindset views.

Table 3
Personal motivational sources to explain increase in fixed mindset in Spring 2022 (baseline data)

	Coef.	*SE*	*t*	*p*-value
Fixed Effects (model of means)				
Intercept γ_{00}	2.58	0.93	2.79	.008**
Time γ_{01}	0.35	0.12	2.80	.006**
Final Grade γ_{02}	-0.08	0.13	-0.57	.582
Course Type: ME 2050 γ_{03}	0.18	0.46	0.400	.686
Course Type: EE 2450 γ_{04}	0.11	0.45	0.25	.778
Mastery Goal γ_{05}	-0.08	0.14	-0.63	.340
Performance Goal γ_{06}	0.26	0.08	3.30	.002**

	Variance	Std. Dev.		
Random Intercept Variance τ^2	0.95	0.97		
Residual Variance σ^2	0.29	0.54		
Note. Intercepts will differ due to the exclusion of missing data. ME 2050 = Strength of Materials, EE 2450 = Embedded Systems Programming I, the reference group is Statics.				

Situational motivational sources (Table 4).

In addition to understanding the personal sources that contributed to students' increase in fixed mindset, we also wanted to understand how the environment may have contributed to students' views about their abilities. First, the average fixed mindset views across students at the beginning of the semester (time 0), in this model, was 2.84 without considering other variables. Over the course of the semester, students change in fixed mindset views increased at a rate of 0.28, $p = .047$. Two situational sources increased students' fixed mindset views. Specifically, students' perception of their classroom environment as one that emphasized performance abilities lead to a significant increase of 0.28 points in their fixed mindset views, $p = .031$. Over the course of the semester, as students continue to be externally recognized as engineers by instructors and peers, their fixed mindset views would be expected to increase at a rate of 0.18, $p = .047$. Conversely, students' fixed mindset views significantly *decreased* when considering the effect of a classroom environment that emphasized mastery goals. A classroom environment that emphasizes mastery is one that values improvement over time, recognizes mistakes as part of learning and is generally a supportive environment [42]. Given the results of this model, we can conclude that a classroom that is structured around principles of mastery, over performance, can have a positive change in students fixed mindsets.

Table 4

Situational motivational sources to explain increase in fixed mindset in Spring 2022 (baseline data)

	Coef.	*SE*	*t*	*p*-value
Fixed Effects				
Intercept γ_{00}	2.84	1.29	2.21	.034*
Time γ_{01}	0.28	0.13	2.05	.047*
Final Grade γ_{02}	-0.03	0.13	-0.25	.806
Course Type: ME 2050 γ_{03}	0.12	0.47	0.26	.793
Course Type: EE 2450 γ_{04}	-0.16	0.45	-0.35	.725
Classroom Mastery Goal γ_{05}	-0.50	0.23	-2.17	.036*
Classroom Performance Goal γ_{06}	0.28	0.13	2.25	.031*
External Recognition γ_{07}	0.18	0.09	2.01	.047*
Random Effects	Variance	Std. Dev.		
Random Intercept Variance τ^2	0.94	0.97		
Residual Variance σ^2	0.29	0.54		

Note. Intercepts will differ due to the exclusion of missing data. ME 2050 = Strength of Materials, EE 2450 = Embedded Systems Programming I, the reference group is Statics.

Limitations and Future Work

This study does not come without limitations. Although gift card incentives were offered to students and multiple announcements were made in class, participation was low. A power analysis was conducted to ensure that the sample used in the pairwise t-test and multilevel model were enough to detect the significant changes and differences, respectively. While the power analysis determined that the sample size was adequate to detect the significant changes, the study could benefit from increasing the sample size. Lastly, future work with an increased sample size will explicitly examine gender and race/ethnicity in the model.

Discussion of Results

We were interested in understanding how students' mindsets changed and the factors that led to those observed changes. We found that students' fixed mindset significantly increased while their growth mindset did not significantly change. However, it is worth acknowledging that the mean value for their growth mindset was larger (mean = 4.21) compared to their fixed mindset score (mean = 2.49). Ultimately, we wanted to understand what might have led to the change and, most importantly, what could be done to mitigate the increase. Thus, we examined two sources of motivation, personal and situational sources. Personal sources of motivation included mastery goals, performance goals, and internal recognition. Situational sources of motivation focused on students' perceptions of their course climate as one that endorsed mastery or performance goals as well as external recognition. The type of course students were enrolled in (i.e., Statics, Strength of Materials, and Embedded Systems Programming I) did not affect changes in students' fixed mindset. It is worth noting that the Embedded Systems course was piloting a pedagogical approach called mastery-based grading, which is an that approach provides retake opportunities on exams with the aim of allowing students' to eventually demonstrate mastery of the learning objectives. Although this course was applying a unique pedagogical intervention, it did not have an impact students' mindset compared to the traditional courses modeled. Additionally, of the students that were surveyed, we found that their final course grade did not impact or help explain the observed increased endorsement of a fixed mindset at the end of the semester. Rather, what explained changes in students' fixed mindset were personal and situational motivational sources.

Of the students surveyed, those who focused on performing well in their course by endorsing a performance-goal orientation showed a greater inclination towards viewing their abilities as fixed. Similarly, believing that the classroom culture was more focused on a performance orientation also increased students' fixed mindset endorsement over the semester. Dweck's early and more recent work continues to conclude that performance goals lead to maladaptive views of beliefs about one's abilities, i.e., that they are fixed [1], [15], [43], and our study further corroborates those claims. However, there are conflicting claims about the effect endorsing a performance goal has on students' academic achievement and self-concept. When a student endorses a performance goal, which is a personal motivation, what they are endorsing is a concern towards proving their abilities and displaying their competence, and this type of goal orientation can create pressure to perform and maintain a particular image of oneself [17], [21]. Yet performance goals have also been shown to produce positive academic outcomes more than mastery goals [17], [21], [22], [44], [45]. For example, among the few studies that applied achievement goal theory in an undergraduate engineering course context, a performance goal positively predicted course grade while mastery goals did not have an effect [22]. As well, in early studies, largely conducted on undergraduate psychology students, performance goal orientation also had positive effects on performance measures such as exams or course grades [45]. Perhaps the truth is that engineering students' endorsement of a performance goal supports both course grade, a gateway towards academic progression, *and* it promotes a fixed mindset. If students believe the currency in their course is performing well (i.e., classroom performance goal structure), then their personal goals align with what they believe are the expectations of their learning environment. The culture of engineering demands that students perform their competence or abilities, and the notion of performing one's competence is part of how students define themselves as engineers [46]–[48]. We have accepted that what it means to see oneself as an engineer includes a display of performance, and the present study shows that a byproduct of endorsing a performance orientation of oneself may also lead to a fixed view of one's ability.

We also found that being recognized as an engineer by instructors and peers over the course of the semester explained the fixed mindset increase for students in our sample. External recognition is an important component to how students come to identify as an engineer [46], [47]. Studies have claimed that external recognition is the most influential component that shapes students' identity [46], [49]. While we are not refuting prior claims, what we are uncovering through our findings is that recognition over time lead to a fixed perception of one's ability for the students in our sample. So, what is it about receiving external recognition that results in a fixed mindset? One possible rationale could be that when students seek bids for recognition, they might be compelled to give the impression that they are already intelligent, capable individuals ready to uphold a positive self-presentation. The "fake it til you make it" aphorism comes to mind; people are more inclined to create an image of themselves (or impression-manage) when they want to influence the impression others form of them. Thus, we need to critically interrogate what it means to seek recognition; even Carlone and Johnson [50] acknowledged that recognition "[could] be viewed as a mechanism for reproducing the status quo" [p. 1207]. Perhaps a byproduct of the engineering status quo may be that it promotes fixed mindset views.

Lastly, for the students in our sample, we found that fixed mindset views could be decreased through a classroom environment that actively promotes mastery goal orientation. A mastery orientation classroom structure was the only source that demonstrated a significant decrease in students' fixed mindset views. Earlier we acknowledge that the mastery-based grading pedagogical intervention used in the Embedded Systems course did not have an impact on students fixed mindsets in comparison to the traditional courses sampled in this study. We postulate that because the course was implementing a pilot version of Mastery-Based Grading with little to no formal implementation support, the mastery classroom orientation focus might not have adequately translated to that group of students. As well, recent systematic review found different ways mastery learning can be implemented which can also have implications on how the pedagogy impacts or does not impact students' mindset [51]. While on the surface, our results may appear contradictory we maintain that with appropriate and structured faculty support Mastery-Based Grading can still have a positive impact on students learning and help decrease their fixed mindset endorsement. Restructuring a course to explicitly support a mastery-goal structure offers a clear remedy to impact students' mindset. It behooves us to carefully evaluate the role that grading plays in developing and reinforcing students' perceptions of the type of learning goal expected in their environment, a critical topic neglected in the engineering education equity conversations. Feldman [52] in his book *Grading for Equity,* asserts that the conventional approach to assessing our students is entrenched in the inequities, biases, and injustices of our education system. Whereas learning does not happen without mistakes, our traditional grading practices that focus on performance rather than mastery communicates to students that mistakes should be punished rather than a normal and expected process of learning. Traditional grading practices in higher education treat assignments, quizzes, and exams as summative assessments of performance. Once students have completed an assessment, there is often little or no opportunity to revisit the content and retake the assessment to improve the grade. The lack of opportunities to revisit content with the aim of retaking assessments for grade improvement results in a higher emphasis on "getting right answers" from the earliest assessment point (e.g., a performance classroom goal). Lewis [53] found that alternative grading systems (e.g., Mastery-Based Grading) promote achievement goal orientations that favor mastery goals over performance and avoidance goals. Mastery-Based Grading focuses on assessing students based on their eventual mastery of the course material rather than performance on a single assessment. Through a Mastery-Based Grading approach, students are given multiple opportunities to revisit and improve their understanding of the course material, in turn, fostering a growth mindset and promoting academic growth and mastery [54], [55]. In a mastery-based graded environment, it is believed that students would be able to grow in their perception of themselves as a learner, focus their attention on mastery and growth and mitigate fixed minded views about their abilities. Our findings provide preliminary insights of the positive effect a mastery-oriented classroom environment can have on a group of minoritized undergraduate engineering students.

Future Work: Institution's New Direction Emphasizing Mastery-Based Grading

The College of Engineering at Cal State Los Angeles has a variety of new directions and attitudes to encourage student success. At Cal State LA, the faculty actively engage in fostering a collaborative and supportive environment that promotes the recognition and valorization of the diverse strengths and lived experiences of our student population, rather than focusing on deficits in academic preparedness. Creating learning environments based on the notion of academic growth and mastery is our new focus. Implementation of Mastery-Based Grading, is part of a larger initiative to transform the College into an ecosystem where all students are given equitable opportunities to thrive and grow. In the three courses studied (i.e., Statics, Strengths of Materials, and Embedded Systems Programming I) we have started redesigning the courses' curriculum to effectuate mastery-based grading. The redesigned courses began rolling out in Fall 2022 and are continuing to roll out across multiple departments in the College as well as at several community college partners in 2023.

The faculty teams in Statics, Strengths of Materials, and Embedded Systems courses are reworking the grading architecture of the courses to encapsulate the four pillars of Mastery-Based Grading, i.e., 1) clearly defined learning outcomes, 2) feedback, 3) marks that indicate progress, and, most importantly, 4) revisions, resubmissions, or reattempts without penalty [56]. Using both the four pillars framework as well as the principles of Universal Design for Learning, the faculty teams have written revised learning outcomes that are directly measurable for mastery, designed course schedules that provide multiple opportunities to demonstrate mastery, prioritized both faculty and peer feedback as part of the learning process and developed rubrics that indicate progress on the specific learning outcomes tied to each assessment. Ultimately, student final course grades are determined by the material that students have mastered by the end of the semester. We believe this new structured and supported implementation might be able to mitigate the increase in students' fixed mindsets and promote growth mindsets. Further research on mindsets and motivation will be conducted in these Mastery-Based Grading course sections.

Conclusion

Our preliminary study has shown that engineering students' fixed mindset indicators increased during the course of a semester in three sophomore course sections, while their growth mindset indicators did not. This is most strongly linked to students' perception of being in a classroom structure which emphasizes performance (i.e., grades). In the next phase of this study, similar measures will be collected in the same three courses, taught by instructors who have engaged in the faculty development for a Mastery-Based Grading classroom structure. This structure is designed to provide an environment in which ultimate mastery, not momentary performance, is emphasized. A similar longitudinal (one semester) study conducted with students in this environment is expected to shed light on whether this translates to a mastery-goal and growth mindset among the students.

References

[1] C. S. Dweck, *Mindset: The New Psychology of Success*. Penguin Random House, 2006.

[2] C. S. Dweck, *Self-Theories: Their Role in Motivation, Personality, and Development*. New York: Psychology Press, 2000. [Online]. Available: https://www.ptonline.com/articles/how-to-get-better-mfi-results

[3] C. S. Dweck and E. L. Leggett, "A Social-Cognitive Approach to Motivation and Personality," vol. 95, no. 2, pp. 256–273, 1988.

[4] C. S. Dweck and D. S. Yeager, "Mindsets: A View From Two Eras," *Perspect. Psychol. Sci.*, vol. 14, no. 3, pp. 481–496, 2019, doi: 10.1177/1745691618804166.

[5] C. S. Dweck, *Mindset: Changing the way you think to fulfil your potential*. Robinson, 2017. [Online]. Available: https://www.ptonline.com/articles/how-to-get-better-mfi-results

[6] A. Rattan, C. Good, and C. S. Dweck, "'It's ok - Not everyone can be good at math': Instructors with an entity theory comfort (and demotivate) students," *J. Exp. Soc. Psychol.*, vol. 48, no. 3, pp. 731–737, 2012, doi: 10.1016/j.jesp.2011.12.012.

[7] D. S. Yeager, R. Johnson, B. J. Spitzer, K. H. Trzesniewski, J. Powers, and C. S. Dweck, "The far-reaching effects of believing people can change: Implicit theories of personality shape stress, health, and achievement during adolescence," *J. Pers. Soc. Psychol.*, vol. 106, no. 6, pp. 867–884, 2014, doi: 10.1037/a0036335.

[8] S. Claro, D. Paunesku, and C. S. Dweck, "Growth mindset tempers the effects of poverty on academic achievement," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 113, no. 31, pp. 8664–8668, 2016, doi: 10.1073/pnas.1608207113.

[9] P. S. Lottero-Perdue and C. P. Lachapelle, "Engineering mindsets and learning outcomes in elementary school," *J. Eng. Educ.*, vol. 109, no. 4, pp. 640–664, 2020, doi: 10.1002/jee.20350.

[10] J. Rhee and C. S. Johnson, "Progress on Longitudinal Study of the Impact of Growth Mindset and Belonging Interventions in a Freshman Engineering Class," in *ASEE Annual Conference & Exposition*, 2019. [Online]. Available: https://works.bepress.com/jinny_rhee/22/

[11] M. Frary, "Encouraging a growth mindset in engineering students," *ASEE Annu. Conf.*

Expo. Conf. Proc., vol. 2018-June, 2018, doi: 10.18260/1-2--30371.
[12] K. J. Reid and D. M. Ferguson, “Assessing Changes in Mindset of Freshman Engineers,” in *2014 ASEE North Central Section Conference*, 2014, p. 7.
[13] J. S. Ge, E. J. Berger, J. Chen, and B. Self, “Do Great Minds Think Alike?: Racial/Ethnic and Gender Differences in Mindset of Undergraduate Engineering Students,” in *Proceedings - Frontiers in Education Conference, FIE*, IEEE, 2018, pp. 0–4. doi: 10.1109/FIE.2018.8659175.
[14] H. L. Henderson, K. E. Rambo-Hernandez, C. Paguyo, and R. A. Atadero, “What is the relationship between mindset and engineering identity for first year male and female students? An exploratory longitudinal study,” *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2017-June, 2017, doi: 10.18260/1-2--29117.
[15] C. S. Dweck, “Motivational Processes Affecting Learning,” *Am. Psychol.*, vol. 41, no. 10, pp. 1040–1048, 1986, doi: 10.1037/0003-066X.41.10.1040.
[16] E. S. Elliott and C. S. Dweck, “Goals: An Approach to Motivation and Achievement,” *J. Pers. Soc. Psychol.*, vol. 54, no. 1, pp. 5–12, 1988, doi: 10.1080/02109395.1989.10821105.
[17] M. L. Maehr and A. Zusho, “Achievement Goal Theory: The Past, Present, and Future,” *Handb. Motiv. Sch.*, vol. 1, no. 1977, 2005.
[18] C. Senko, C. S. Hulleman, and J. M. Harackiewicz, “Achievement goal theory at the crossroads: Old controversies, current challenges, and new directions,” *Educ. Psychol.*, vol. 46, no. 1, pp. 26–47, 2011, doi: 10.1080/00461520.2011.538646.
[19] C. S. Hulleman, S. M. Schrager, S. M. Bodmann, and J. M. Harackiewicz, “A Meta-Analytic Review of Achievement Goal Measures: Different Labels for the Same Constructs or Different Constructs With Similar Labels?,” *Psychol. Bull.*, vol. 136, no. 3, pp. 422–449, 2010, doi: 10.1037/a0018947.
[20] C. Ames, “Clasrooms: Goals, Structures, and Motivation,” *J. Educ. Psychol.*, vol. 84, no. 3, pp. 261–271, 1992.
[21] C. Senko, “Achievement goal theory: A story of early promises, eventual discords, and future possibilities,” *Handb. Motiv. Sch. Second Ed.*, pp. 75–95, 2016, doi: 10.4324/9781315773384.
[22] N. J. Hunsu, O. P. Olaogun, A. V. Oje, P. H. Carnell, and B. Morkos, “Investigating students’ motivational goals and self-efficacy and task beliefs in relationship to course attendance and prior knowledge in an undergraduate statics course,” *J. Eng. Educ.*, no. May 2021, pp. 108–124, 2023, doi: 10.1002/jee.20500.
[23] J. M. Harackiewicz, K. E. Barron, and A. J. Elliot, “Rethinking achievement goals: When are they adaptive for college students and why?,” *Educ. Psychol.*, vol. 33, no. 1, pp. 1–21, 1998, doi: 10.1207/s15326985ep3301_1.
[24] J. M. Harackiewicz, K. E. Barron, J. M. Tauer, S. M. Carter, and A. J. Elliot, “Short-term and long-term consequences of achievement goals,” *J. Educ. Psychol.*, vol. 92, no. 2, pp. 316–330, 2000.
[25] A. J. Elliot and H. A. McGregor, “A 2 × 2 achievement goal framework,” *J. Pers. Soc. Psychol.*, vol. 80, no. 3, pp. 501–519, 2001, doi: 10.1037/0022-3514.80.3.501.
[26] W. Law, A. J. Elliot, and K. Murayama, “Perceived competence moderates the relation between performance-approach and performance-a voidance goals,” *J. Educ. Psychol.*, vol. 104, no. 3, pp. 806–819, 2012, doi: 10.1037/a0027179.
[27] R. Kumar, A. Zusho, and R. Bondie, “Weaving Cultural Relevance and Achievement

Motivation Into Inclusive Classroom Cultures," *Educ. Psychol.*, vol. 53, no. 2, pp. 78–96, 2018, doi: 10.1080/00461520.2018.1432361.

[28] E. L. Usher, "Acknowledging the Whiteness of Motivation Research: Seeking Cultural Relevance," *Educ. Psychol.*, vol. 53, no. 2, pp. 131–144, 2018, doi: 10.1080/00461520.2018.1442220.

[29] R. Mark, "The Self-Presentational Motive," in *Self presentation : impression management and interpersonal behavior /*, 1995, pp. 39–64.

[30] G. A. Garcia, *Becoming Hispanic-serving institutions: Opportunities for colleges and universities*. Johns Hopkins University Press, 2019.

[31] G. E. Dunkleberger and H. W. Heikkinen, "Mastery Learning: Implications and Practices," *Sci. Educ.*, vol. 67, no. 5, pp. 553–560, 1983.

[32] A. Baisley and K. D. Hjelmstad, "What do Students Know after Statics? Using Mastery-based Grading to Create a Student Portfolio," *ASEE Annu. Conf. Expo. Conf. Proc.*, 2021.

[33] R. L. Armacost and J. Pet-armacost, *Using mastery-based grading to faciliate learning*, (2003).

[34] B. S. Bloom, "Learning for Mastery," *Eval. Comment*, vol. 1, no. 2, 1968.

[35] C. Midgley *et al.*, "Manual for the Patterns of Adaptive Learning Scales." pp. 734–763, 2000.

[36] A. Godwin, "The development of a measure of engineering identity," *ASEE Annu. Conf. Expo. Conf. Proc.*, vol. 2016-June, 2016, doi: 10.18260/p.26122.

[37] M. Tavakol and R. Dennick, "Making sense of Cronbach's alpha," *Int. J. Med. Educ.*, vol. 2, pp. 53–55, 2011, doi: 10.5116/ijme.4dfb.8dfd.

[38] P. J. Curran, S. G. West, and J. F. Finch, "The Robustness of Test Statistics to Nonnormality and Specification Error in Confirmatory Factor Analysis," vol. 1, no. 1, pp. 16–29, 1996.

[39] B. Muthen and D. Kaplan, "A Comparison of some Methodologies for the Factor-Analysis of Non-Normal Likert Variables," *Br. J. Math. Stat. Psychol.*, vol. 45, pp. 19–30, 1992, doi: 10.1111/j.2044-8317.1985.tb00832.x.

[40] F. Faul, E. Erdfelder, A. Buchner, and A. G. Lang, "Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses," *Behav. Res. Methods*, vol. 41, no. 4, pp. 1149–1160, 2009, doi: 10.3758/BRM.41.4.1149.

[41] R Core Team, "R: A Language and Environment for Statistical Computing." Vienna, Austria, 2019.

[42] E. M. Skaalvik and R. A. Federici, "Relations between classroom goal structures and students' goal orientations in mathematics classes: When is a mastery goal structure adaptive?," *Soc. Psychol. Educ.*, vol. 19, no. 1, pp. 135–150, 2016, doi: 10.1007/s11218-015-9323-9.

[43] C. S. Dweck and D. C. Molden, "Mindsets: Their Impact on Competence Motivation and Acquisition," in *Handbook of Competence and Motivation Theory and Application*, A. J. Elliot, C. S. Dweck, and D. S. Yeager, Eds., Second.2017, pp. 135–154.

[44] C. Senko and K. M. Miles, "Pursuing their own learning agenda: How mastery-oriented students jeopardize their class performance," *Contemp. Educ. Psychol.*, vol. 33, no. 4, pp. 561–583, 2008, doi: 10.1016/j.cedpsych.2007.12.001.

[45] A. J. Elliot and K. Murayama, "On the Measurement of Achievement Goals: Critique, Illustration, and Application," *J. Educ. Psychol.*, vol. 100, no. 3, pp. 613–628, 2008, doi: 10.1037/0022-0663.100.3.613.

[46] A. Godwin and A. Kirn, “Identity-based motivation: Connections between first-year students’ engineering role identities and future-time perspectives,” *J. Eng. Educ.*, vol. 109, no. 3, pp. 362–383, 2020, doi: 10.1002/jee.20324.
[47] D. Verdín, “The Power of Interest: Minoritized Women’s Interest in Engineering Fosters Persistence Beliefs Beyond Belongingness and Engineering Identity,” *Int. J. STEM Educ.*, vol. 8, no. 33, pp. 1–19, 2021.
[48] H. B. Carlone and A. Johnson, “Understanding the Science Experiences of Successful Women of Color: Science Identity as an Analytic Lens,” *J. Res. Sci. Teach.*, vol. 44, no. 8, pp. 1187–1218, 2007, doi: 10.1002/tea.
[49] S. Rodriguez, K. Cunningham, and A. Jordan, “STEM Identity Development for Latinas: The Role of Self- and Outside Recognition,” *J. Hispanic High. Educ.*, vol. 18, no. 3, pp. 254–272, 2019, doi: 10.1177/1538192717739958.
[50] H. Carlone and A. Johnson, “Understanding the Science Experience of Sucessful Women of Color: Science Identity as an Analytic Lens,” *J. Res. Sci. Teach.*, vol. 44, no. 8, pp. 1187–1218, 2007, doi: 10.1002/tea.
[51] C. Perez Leon and D. Verdin, “A Systematic Literature Review for Mastery Learning in Undergraduate Engineering Courses,” *Int. J. Eng. Educ.*, p. in press, 2023.
[52] J. Feldman, *Grading for equity: What it is, why it matters, and how it can transform schools and classrooms*. Corwin Press, 2018.
[53] D. Lewis, “Impacts of Standards-Based Grading on Students’ Mindset and Test Anxiety,” *J. Scholarsh. Teach. Learn.*, vol. 22, no. 2, pp. 67–77, 2022, doi: 10.14434/josotl.v22i2.31308.
[54] R. Campbell, D. Clark, and J. OShaughnessy, “Introduction to the Special Issue on Implementing Mastery Grading in the Undergraduate Mathematics Classroom,” *Primus*, vol. 30, no. 8–10, pp. 837–848, 2020, doi: 10.1080/10511970.2020.1778824.
[55] O. E. Fernandez, “Second Chance Grading: An Equitable, Meaningful, and Easy-to-Implement Grading System that Synergizes the Research on Testing for Learning, Mastery Grading, and Growth Mindsets,” *Primus*, 2020, doi: 10.1080/10511970.2020.1772915.
[56] R. Talbert, “Finding common ground with grading systems: We’ve seen the differences. Now what are the similarities?,” *Grading for Growth*, 2021. https://gradingforgrowth.com/p/finding-common-ground-with-grading (accessed Jan. 27, 2023).