Paper Title Classroom Goal Structures Impact Mindsets: A Study of Undergraduate Engineering Students at a Hispanic-Serving Institution

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Background

Research on mindsets has spanned decades from Dweck and colleagues' earliest work (Dweck, 1986; Elliott & Dweck, 1988), with many researchers contributing to its development. Mindset theory focuses on an individual's responses to challenges or setbacks (Yeager & Dweck, 2020). Specifically, mindset theory sought to answer the following question, "why [do] students with roughly equal ability show different attributions and responses to a failure situation" (Yeager & Dweck, 2020, p. 3). The attribution an individual assigns to themselves after a failure is based on a belief system about their ability; either it is malleable and can grow over time, or it is fixed and cannot be changed (Dweck, 1986, 2006).

An individual's belief about their abilities informs the types of goals they adopt. Individuals who believed their intelligence was malleable and capable of developing over time adopt learning-focused goals (i.e., mastery goals). Conversely, individuals with an entity view of their intelligence are likelier to adopt performance goals (Dweck, 1986; Dweck & Yeager, 2019; Elliott & Dweck, 1988). A recent review of the controversies of mindset theory affirmed a positive association between mindset and academic achievement, and the effect is more significant among struggling students (Yeager & Dweck, 2020). Mindset-focused research has made a significant impact in academic circles, garnering widespread attention, yet "it is time to turn more seriously to an examination of the mindsets conveyed by or embodied in the environment that students are in" (Dweck & Yeager, 2019, p. 490).

Scholars who have reinvigorated the application of mastery learning contend that a class environment that focuses on *developing* ability through multiple opportunities creates a growth mindset (Cilli-Turner et al., 2020; Fernandez, 2020), albeit empirical evidence was not provided. Therefore, in this study, we sought to provide evidence of how a mastery learning environment affected undergraduate engineering students' beliefs about their abilities. We also use achievement goal theory to inform how students' perceptions of the classroom goal structure inform their mindset.

Purpose

Several gateway engineering courses have historically had 50% fail rates at one Hispanic-Serving Institution. Yet, successful completion of these courses is paramount as they are prerequisites for advancing to upper-level coursework. Moreover, the knowledge gained in these courses holds the utmost importance for the success of subsequent courses. Therefore, this study examined how undergraduate students' mindsets were impacted in three engineering courses that applied principles of mastery learning. Specifically, we sought to answer the following research question:

1) Do students' perceptions of their classroom climate influence their mindset?

A Mastery Learning Intervention: Building a Growth Mindset Culture

Mastery learning recognizes that mastery is not always achieved on the first attempt, and learning from mistakes and perseverance is fundamental to learning (Bloom, 1971; Carroll, 1963). While mastery learning is not a new approach, it has seen a resurgent interest from engineering educators and college mathematics instructors (Campbell et al., 2020; Perez Leon & Verdin, 2023). A recent systematic review found that most published articles implementing mastery learning in engineering were between 2013 and 2020, signaling a renewed interest (Perez Leon & Verdin, 2023). Two studies found an increase in B-range final grades on sections that applied mastery learning compared to those that did not (Helmke, 2019; Okamoto, 2020). In a one-year Circuit course sequence, after implementing mastery learning, Leonard et al. (Leonard et al., 2008) found that the pass rate for minoritized students increased from 55% to 90%.

In this study, three courses underwent a curriculum redesign to facilitate mastery learning (Verdin et al., 2023). The redesigned courses and a faculty learning community occurred in the Fall of 2022. The faculty teams in the three courses reworked the grading architecture of the courses to encapsulate the four pillars of mastery learning, i.e., 1) clearly defined learning outcomes, 2) feedback, 3) marks that indicate progress, and, most importantly, 4) reattempts without penalty. 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 faculty, and peer feedback as part of the learning process, and developed rubrics that indicate progress on the specific learning outcomes of each assessment.

Theoretical framework

Achievement goal theory was intended to help researchers understand students' motivational pursuits and engagement in learning tasks, that is, either motivation is driven by personal goals focused on development or performance (Elliott & Dweck, 1988; Kaplan et al., 2002; Maehr & Zusho, 2005; Senko, 2016). Despite the extensive body of work, a challenge still facing achievement goal theory is a lack of understanding of "how schools and classroom goal structures influence student motivation and behavior" (Urdan & Kaplan, 2020, p. 5).

Classrooms are also spaces where the messages transmitted by the environment can influence the salience of a certain goal and, in turn, its adoption (Ames, 1992). Classroom goal structures extend beyond personal goals (i.e., mastery, performance, etc.) to encompass students' perceptions of the goal aims communicated in their classroom environment. Classroom goal structures encompass the practices and shared beliefs or norms within a classroom that emphasize the significance of mastery or performance goals (Urdan, 2010). Classroom *mastery* goal structure emphasizes that classroom messages and practices are focused on developing competency, while classroom *performance* goal structure conveys that the class environment is focused on demonstrating competence (Anderman & Patrick, 2012; Urdan, 2010). Few studies have examined classroom goal structures and their effect on students' achievement motivation or outcomes (Urdan, 2010), and the authors have found no study focusing on undergraduate engineering students.

Method

Data came from a study of three sophomore-level engineering courses (i.e., Statics, Strength of Materials, and Embedded Systems Programming I) at one Hispanic-Serving Institution (HSI) in the Southwest with a high enrollment of Latinx students. Data were collected at two-time points

(beginning and end of semester) across three semesters. A summary of students' demographics can be found in Table 1.

We used the general mindset scale developed by Dweck (2006). The classroom goal structure used in this study was borrowed from Patterns of Adaptive Learning Scales (PALS; (Midgley et al., 2000). Detailed information about the survey scales used in this study and their corresponding internal reliability scores can be found in Table 2 in the Appendix.

Table 1
Overall demographics of Engineering Students

	Overall	**Spring 2022**	**Fall 2022**	**Spring 2023**
Total	117	38	36	43
Women	31 (26%)	10	8	13
Men[+]	86 (74%)	28	28	30
Mastery Learning Course (MLC)				
Yes	82 (70%)	14[*]	25	43
No	35 (30%)	24	11	0
Course Type				
ME 2010	33 (28%)	11	10	12
ME 2050	59 (50%)	13	19	27
EE 2450	25 (21%)	14	7	4
Race/Ethnicity[++]				
Asian	24	12	6	6
Black or African American	1	0	1	0
Latina or Hispanic	84	23	26	35
Middle Eastern	3	1	1	1
Native African	0	0	0	0
Native Hawaiian/Other Pacific Islander	1	1	0	0
Native American/ Alaska Native	1	0	1	0
White	11	4	1	6
Race/ethnicity not listed above	3	1	2	0
Parents' Level of Education				
First-generation college students	82 (70%)	27	27	28
Continuing-generation college students	25 (30%)	11	9	5

Note. [+]Students also specified they were cisgender.
[++]Students were allowed to select all that apply for their race/ethnicity therefore the sample size will appear higher.
*Instructor teaching the Spring 2022 MLC courses did not participate in the Faculty Learning Community aimed at supporting instructors' mastery learning implementation.

Data Analysis Procedure

A linear mixed model was used to answer the research question: *do students' perceptions of their classroom climate influence their mindset?* We used repeated measures in our analysis. The Level-1 variables were based on measures collected at multiple time points and intended to capture within-student variation. Level 2 variables were between-student variables (e.g., gender, race/ethnicity, semester, etc.). Two models were run to evaluate growth and fixed mindsets separately. The interclass correlation (ICC) for the growth and fixed mindset models was 71% and 73%, respectively. The within-student mean differences over time were 29% for the growth mindset model and 27% for the fixed mindset model. Final models were evaluated for adequacy; specifically, we examined normality, homogeneity of variance, and homoscedasticity, and all were found to be acceptable.

Results

A summary of the variable correlations can be found in Table 3; the following correlations were examined final course grade, persistence beliefs, mindsets, and classroom goal structures. We found no significant correlation between final course grade, growth, or fixed mindsets. However, students' persistence beliefs, measured using the following: *I feel certain about graduating with an engineering degree*, positively correlated with final course grade. A high positive correlation was also found between students' persistence beliefs and growth mindset.

Table 3.
Correlations, variable mean and standard deviation on diagonal, and standard deviation in parenthesis

	V1	V2	V3	V4	V5	V6	V7
V1: Final Grade	1.56 (1.54)						
V2: Persistence Beliefs	.18**	5.57 (1.57)					
V3: Growth Mindset	.08	.48***	4.58 (1.11)				
V4: Fixed Mindset	-.10	-.28***	-.50***	1.94 (1.35)			
V5: Class Mastery Goal Structure	.03	.34***	.23*	-.17*	5.30 (.83)		
V6: Class Performance Goal Structure	-.09	.00	.01	.14*	.10	4.55 (1.13)	
V7: Class Performance-Avoidance Goal Structure	.03	-.19**	-.23***	.34***	-.14*	.21**	2.29 (1.57)

Note: *$p \leq .05$ level; **$p \leq .01$ level; ***$p \leq .001$ level.

Classroom goal structures inform students' mindset change

For each mindset construct, two models were examined. The first model included only demographic information about the participants, gender, race/ethnicity, semester, course type, and a variable distinguishing between those enrolled in a mastery learning course. The second model considered students' perceptions of their learning environment and significant interaction effects. A summary of the models can be found in Table 4.

Growth Mindset Model

Latinx students were more likely to have a higher growth mindset score compared to all other students (0.52, $p < .01$). Students surveyed in Spring 2023 had a significant increase in their growth mindset score (0.38, $p < .01$). Notably, all students sampled in Spring 2023 were enrolled in courses that implemented mastery learning; in contrast, the reference group was based on a sample of students not enrolled in mastery learning courses. Additionally, a classroom climate that promoted messages focused on development and mastery (i.e., classroom mastery goal structure) would significantly increase students' growth mindset views by 0.13 points ($p < .05$). Lastly, a classroom environment that promoted performance-avoidance goals would have a significantly negative impact on Latinx students' growth mindset, decreasing it by -0.45 points.

Fixed Mindset Model

We found that Latinx students benefited the most from the mastery learning intervention. Specifically, Latinx students who were enrolled in a mastery learning course were expected to have a significant decrease in their fixed mindset score (-0.33, $p < .05$). Conversely, all other students who were not Latinx but who enrolled in a mastery learning course were expected to have a significant increase in their fixed mindset score (0.93, $p < .01$). Students' who were not in mastery learning courses and perceived that their classroom climate emphasized a classroom performance goal structure showed a significant increase in fixed mindset views (0.24, $p < .05$). Conversely, those who experienced a mastery learning environment and believed their classroom climate promoted performance messages showed a reduction in fixed mindset views (-0.64, $p < .01$).

Students in a mastery learning course who believed their classroom climate was focused on avoiding appearing incompetent showed a significant decrease in fixed mindset views by -0.26 points ($p < .05$). First-generation college students were more likely to endorse fixed views about their abilities compared to their counterparts (0.36, $p < .01$). However when combined with the perception of their classroom emphasizing a performance-avoidance goal structure, first-generation college students exhibited a notable reduction in fixed mindset views (-0.36, $p < .05$).

Scholarly Significance

Students' mindsets about their abilities are malleable, can change over time, and the learning environment can communicate messages that can undermine how one perceives their abilities (Canning et al., 2019, 2022; Dweck, 2006). Studies have found that negative messages from instructors communicating fixed views of one's abilities lead students to withdraw from their course (Rattan et al., 2012) and induce stereotype threats for women (Canning et al., 2022). While recent publications focused on applying mastery learning, assert that this approach promotes a growth mindset due to the positive messages focused on developing knowledge (e.g., (Clark & Talbert, 2023; Feldman, 2018; Fernandez, 2020), empirical evidence to support the claim is lacking. The types of goals students pursue are intertwined by the messages transmitted in the learning environment, students' identities, and socio-historical legacies of racialized schooling practices (Urdan & Kaplan, 2020), all of which can impact students' mindsets about their abilities. Therefore, it is imperative to understand how transmitting different goal messages in the classroom impacts diverse students' mindsets. We examined how the classroom environment, through the implementation of mastery learning and goal structures, impacted the mindsets of a predominantly minoritized group of students.

Our models affirm that there is evidence that mastery learning enhances one's growth mindset for some students and promotes a fixed mindset for others. In Spring 2023, all students in the dataset were enrolled in a mastery learning course, compared to the reference group. The Spring 2023 cohort showed an increase in growth mindset over the semester, providing evidence of the effectiveness a mastery learning environment has in promoting a growth mindset. Alternatively, when aggregating students enrolled in the mastery learning curricular intervention across the three semesters, we find that the learning intervention promoted a fixed mindset. However, when examining interaction effects, we found mastery learning students' fixed mindset decreased through a classroom environment emphasizing performance and performance-avoidance messages. Scholars confirmed that classrooms can encompass multiple goal structures; the messages transmitted in the environment can stimulate diverse goal structures (Kaplan et al., 2002). Also, depending on who the student is (i.e., Latinx vs. first-generation college student), their interpretation of the goal structure can have adaptive or maladaptive implications toward endorsing a fixed mindset. A mastery learning curricular intervention is not enough to promote a growth mindset and mitigate the endorsement of a fixed mindset; rather, educators need to be attuned to the messages transmitted in the classroom and how students interpret the environment.

Table 4
Classroom motivational sources predict changes in Students' Mindset in standardized form.

	Growth Mindset		**Fixed Mindset**	
	Model 1	Model 2	Model 1	Model 2
Fixed Effects				
Intercept	0	0	0	0
Time	0.03 (.03)	0.06 (.04)	0.05 (.03)	0.03 (.04)
Gender (reference males)	-0.03 (.08)	-0.01 (.07)	-0.01 (.08)	-0.04 (.07)
Latinx (reference all other students)	0.24 (.08)**	0.52 (.11)***	-0.24 (.08)**	-0.33 (.16)*
First-Generation College Student (FGCS)	-0.15 (.08) $^{+}$	-0.16 (.08)*	0.15 (.09) $^{+}$	0.36 (.13)**
Mastery Learning Course (MLC)	-0.11 (.12)	-0.11 (.11)	0.01 (.09)	0.93 (.28)**
Fall 2022 (reference Spring 2022)	0.03 (.10)	0.09 (.09)	-0.14 (.13)	-0.12 (.10)
Spring 2023 (reference Spring 2022)	0.37 (.14)**	0.38 (.13)**	-0.14 (.11)	-0.08 (.14)
ME 2050 (reference EE2450)	0.23 (.13) $^{+}$	0.20 (.12)	-0.11 (.15)	-0.13 (.13)
ME2010 (reference EE2450)	0.11 (.12)	0.10 (.11)	-0.06 (.13)	-0.10 (.11)
Classroom Mastery Goal Structure		0.13 (.06)*		-0.07 (.06)
Classroom Performance Goal Structure		-0.01 (.05)		0.24 (.10)*
Classroom Performance Avoidance Goal Structure		0.16 (.10)		0.33 (.17)$^{+}$
Interaction Effects				
Latinx*Classroom Performance Avoidance Goal Structure		-0.45 (.13)***		0.46 (.15)**
Latinx*MLC				-0.33 (.17)*
MLC* Classroom Performance Goal Structure				-0.64 (.25)**
MLC*Classroom Performance Avoidance Goal Structure				-0.26 (.14)*
FGCS* Classroom Performance Avoidance Goal Structure				-0.36 (.18)*
Random Effects				
Random Intercept Variance	0.66	0.48	1.15	0.81
Residual Variance	0.34	0.34	0.50	0.53
Pseudo-R^2		0.73		0.72

Note. ME 2050 = Strength of Materials, ME2010 = Statics, reference group is EE 2450 = Embedded Systems Programming I;
$^{+}$ $p \leq .09$ level; *$p \leq .05$ level; **$p \leq .01$ level; ***$p \leq .001$ level.

Appendix

Tables 2
Survey measured used in the study, all measured were collected twice (i.e., beginning and end of semester

	Definition	**Example Survey Measures**	**Cronbach Alpha**
Prompt: To what extent do you agree or disagree with the following statements?			
Growth Mindset	Belief that abilities can be developed or grow over time.	• You <u>can</u> change even your basic intelligence level considerably. • No matter who you are, you <u>can</u> significantly change your level of talent. • You <u>can</u> always substantially change how much talent you have.	Time 1 = 0.82 Time 2 = 0.82
Fixed Mindset	Belief in a natural ability or have a certain amount of ability that cannot be changed.	• Your intelligence is something about you that you <u>can't</u> change very much. • You can learn new things, but you <u>can't</u> really change your basic intelligence. • You are a certain kind of person, and there is not much that can be done to really change that	Time 1 = 0.79 Time 2 = 0.81
Goal Structure prompt: Students were asked to rate how true they felt the statements were about their respective courses.			
Class Mastery Goal Structure	Students' perceptions that the purpose of engaging in academic work in their course is to *develop* competence.	• In this course, trying hard is very important. • In this course, how much you improve is really important. • In this course, really understanding the material is the main goal.	Time 1 = 0.86 Time 2 = 0.83
Class Performance Goal Structure	Students' perceptions that the purpose of engaging in academic work in their course is to *demonstrate* competence.	• In this course, getting good grades is the main goal. • In this course, getting right answers is very important. • In this course, it's important to get high scores on tests.	Time 1 = 0.73 Time 2 = 0.73
Class Performance-Avoidance Goal Structure	Students' perceptions that the purpose of engaging in academic work in their current course is to *avoid demonstrating incompetence*	• In this course, it's important that you don't make mistakes in front of everyone. • In this course, it's important not to do worse than other students. • In this course, one of the main goals is to avoid looking like you can't do the work.	Time 1 = 0.91 Time 2 = 0.88

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