Entrepreneurial Mindset in Early Engineering: A Baseline Assessment in Large Introductory Mechanics Courses

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Abstract

The entrepreneurial mindset (EM) consists of three key elements: Curiosity, Connections, and Creating Value (the 3Cs), which empower students to approach problems creatively and with purpose. Fostering this mindset helps produce engineers who can combine technical expertise and critical thinking with innovative approaches to problem-solving. Equally important is the ability to communicate technical ideas effectively, particularly to non-technical audiences. To help engineering students thrive in their careers after graduation, it is critical to provide them with the right tools during their education. While prior work has examined EM development through targeted instructional interventions, less is known about how students perceive and develop these attributes within traditional engineering courses that are not explicitly designed to cultivate EM. To characterize these perceptions, we conducted surveys in three large introductory mechanics courses (Statics, Dynamics, and Solid Mechanics) at a large Midwest university. The surveys included four Likert-scale questions (one for each of the 3Cs and one for Fluency) and were administered at the start and end of the semester, as well as at the conclusion of each topic-based unit. Students consistently reported high perceived Value of course content to their future careers, both at the start and end of the semester, indicating a stable recognition of relevance. In contrast, Curiosity, Connections, and Fluency exhibited variability across courses and topics; however, changes over the semester were generally small. Because the study reflects a single semester and relies on voluntary self-reported data, the findings are best interpreted as preliminary evidence contributing to a developing understanding of baseline EM perceptions in foundational mechanics education rather than definitive conclusions about instructional impact. These results provide an initial reference point for future course offerings that intentionally integrate EM-focused activities and evaluate whether targeted interventions produce measurable and repeatable changes in student perceptions.

Introduction

An entrepreneurial mindset (EM) empowers engineering students to thrive in a rapidly changing workforce [1, 2]. As workforce needs become more fast-paced and complex, it is becoming increasingly important for students to develop this mindset during college [1–3]. Employers expect engineers to pair strong analytical and technical skills with entrepreneurial competencies such as creative problem-solving, strategic thinking, and effective communication [3]. This expectation aligns with engineers' growing presence in leadership roles: many Fortune 500 CEOs hold engineering degrees [4, 5]. As a result, there has been significant interest in promoting EM development within engineering education [6–9].

A mindset, comprising attitudes, motivations, and dispositions, is more difficult to teach and assess than technical skills. To support EM development, the Kern Entrepreneurial Engineering Network (KEEN) framework defines three measurable attributes: Curiosity (a desire to explore and understand the changing world), Connections (the ability to integrate information from many sources), and Creating Value (focusing on delivering societal, economic, or personal impact) [6, 8, 9]. These "3Cs" are strengthened through active learning strategies [10, 11]. Demonstrations, in particular, offer an accessible form of active learning for large lecture courses and have been shown to enhance both conceptual understanding and student performance [11–13]. To design targeted demonstrations that support EM, it is critical to first understand the baseline entrepreneurial perceptions of engineering students.

While prior work in engineering education has largely focused on designing, implementing, and assessing pedagogical interventions to develop the EM through the integration of real-world contexts [14, 15], projects [16, 17], and e-learning modules [18], there is a gap in our inherent understanding of EM within a traditional engineering curriculum. To address this gap, we have examined how students perceive the 3Cs and technical communication Fluency within traditional mechanics courses that were not intentionally designed to include EM-focused interventions. Rather than evaluating the impact of a specific pedagogical strategy, this work characterizes how student perceptions shift from the beginning to the end of the semester and across topic-based units within the natural structure of these courses.

In this study, surveys focused on the 3Cs and Fluency were administered at the beginning and end of the semester, as well as at the end of each unit (seven per course, defined by topics) in three introductory mechanics courses (Statics, Dynamics, and Solid Mechanics). This study provides an initial reference point for understanding EM attributes in foundational mechanics coursework by documenting EM perceptions across time points and topics. These findings can inform the design of future interventions to strengthen EM development in fundamental engineering courses.

Methods

This study was classified as non-human subjects research by the University of Illinois Institutional Review Board (#IRB25-1150). All participants in the study gave informed consent.

Courses

Survey data was collected from introductory Statics, Dynamics, and Solid Mechanics courses at the University of Illinois Urbana-Champaign in the Fall 2025 semester. All courses are traditional lectures that meet three times per week in a large classroom, with smaller weekly discussion sessions. Courses are 16 weeks long, with some Statics students only enrolled in "Introduction to Statics", which is the first 10 weeks of the semester. There were two sections of Statics with different instructors using shared course materials and notes. Dynamics and Solid Mechanics each consisted of one section, each with their respective instructors. Statics is a prerequisite for Dynamics and Solid Mechanics, while the later two can be taken simultaneously. The number of students enrolled Fall 2025 were 390 in Statics section 1, 471 in Statics section 2, 245 in Dynamics, and 221 in Solid Mechanics. Responses from both sections were combined for Statics.

Start and end of semester EM survey

Beginning and end of semester data were collected using four Likert Scale questions chosen to gain insight into students' perception of the course content as it relates to entrepreneurial mindset. The prompt given was "select how well you agree with the questions" and the response levels were: 1 = "Not at all", 2 = "Slightly", 3 = "Moderately", 4 = "Very", and 5 = "Extremely". The following questions were assessed through surveys at the start (the 6^{th} week of instruction) and end (the 13^{th} week, before fall break and final exams for full courses, and the 9^{th} week for the "Introduction to Statics" course) of the semester via Qualtrics.

<u>Likert Scale questions:</u>

1. Q1, Curiosity: "To what extent does the content in this course stimulate your Curiosity about real-world problems?"
2. Q2, Connections: "How confident are you in your ability to connect content in this course to the design of everyday objects?"
3. Q3, Creating Value: "How helpful do you feel the content in this course will be for your future career as an engineer?"
4. Q4, Fluency: "How confident are you in your ability to explain a key concept from this course to a friend or family member who is not an engineer?"

Students' responses collected at the start and end of the semester were treated as numeric variables with values 1-5 and were not normally distributed (Shapiro-Wilk). To compare differences in responses between questions and between start and end, post-hoc Wilcoxon signed-rank tests (paired) with Bonferroni correction were used. All tests were performed in R (v4.2.2).

Unit-specific EM survey

In addition to the beginning and end of the semester, topic-specific survey data were also collected following the completion of each unit. The survey consisted of the same four Likert-scale questions, except they were rephrased to ask about the content in a specific <u>unit</u> instead of the <u>course</u> as a whole. The topics of each unit of each course are described in Supplemental Table 2.

Additional Analysis

Students' EM responses at the end of the semester from Qualtrics were paired with final exam grade data. Students who didn't receive a grade for the final exam or received a score of 0% were removed. Final exam grades were standardized (z-score) for each course. Multiple linear regression models were used to correlate standardized final exam grades with EM responses for each course. All regressions were performed with the statsmodels (v0.14.5) library for Python.

Results

The total number of students who responded and consented at both the start and end of semester were 164 in Statics (19.0%), 77 in Dynamics (31.4%), and 28 (12.7%) in Solid Mechanics. The overall response rate was 20.3%.

Baseline course EM perception

Across the three courses, median answers at the start and end of the semester were mainly "Moderately" and "Very" for all questions (Table 1). The median Creating Value responses did not change from start to end of the semester in any of the courses, staying consistently high ("Very"). In Statics, Dynamics, and Solid Mechanics, 43.3% , 51.9%, and 53.6% of students, perceived the content in the courses to be "very" helpful for their future career as an engineer at the start of the semester, and 43.3% , 46.8%, and 46.4% at the end, respectively. Median Fluency increased from "Moderately" to "Very": 40.2%, 40.3%, and 60.7% of students in Statics, Dynamics, and Solid Mechanics, respectively, were "Very" confident in their ability to explain a key concept from the course to a non-technical audience.

Table 1: Summary of numerical median responses from start and end of semester surveys (1 = "Not at all", 2 = "Slightly", 3 = "Moderately", 4 = "Very", and 5 = "Extremely")

	Question	Median		p value
		Start	End	Start vs End
Statics N = 164	Curiosity	3	4	$<$**0.001**
	Connections	4	4	**0.024**
	Value	4	4	1.000
	Fluency	3	4	**0.006**
Dynamics N = 77	Curiosity	4	4	0.377
	Connections	3	4	0.260
	Value	4	4	1.000
	Fluency	3	4	**0.010**
Solid Mechanics N = 28	Curiosity	4	3	1.000
	Connections	4	3	1.000
	Value	4	4	1.000
	Fluency	3	4	0.566

Curiosity and Connections exhibited course-dependent trends (Table 1). In Statics, Curiosity increased from a median of "Moderately" to "Very", while Connections remained high (median =

“Very”). In Dynamics, the opposite trend was observed: Curiosity remained consistently high (median = “Very”) while Connections increased from “Moderately” to “Very”. In contrast, Solid Mechanics showed a decrease in both Curiosity and Connections, from “Very” at the start of the semester to “Moderately” at the end. At the end of the semester, most students’ Curiosity and confidence in making Connections with real-world problems were “Very” stimulated by the content in Statics (Curiosity 42.68% and Connection 45.7%) and Dynamics (37.7% and 44.2%), but only “Moderately” in Solid Mechanics (53.6% in both).

Pairwise statistical comparisons of response distributions were conducted to evaluate differences among attributes and between the start and end of the semester. In Statics, at the start of the semester, the distribution of responses for Creating Value differed significantly from all other questions ($p < 0.01$ for all comparisons), exhibiting the most positive response distribution (Figure 1). Creating Value was the only attribute for which responses of “Very” and “Extremely” exceeded 50% of the total and for which zero “Not at all” responses were observed. At the start, Fluency and Connections exhibited similar response distributions, while Curiosity was perceived less positively than Connections ($p < 0.001$) (Figure 1). There were significant positive increases in Curiosity ($p < 0.001$), Connections ($p = 0.024$), and Fluency ($p = 0.006$) from the start to the end of the semester. At the end of the semester, Creating Value continued to be perceived significantly more positively than Fluency ($p = 0.019$) and Curiosity ($p < 0.001$).

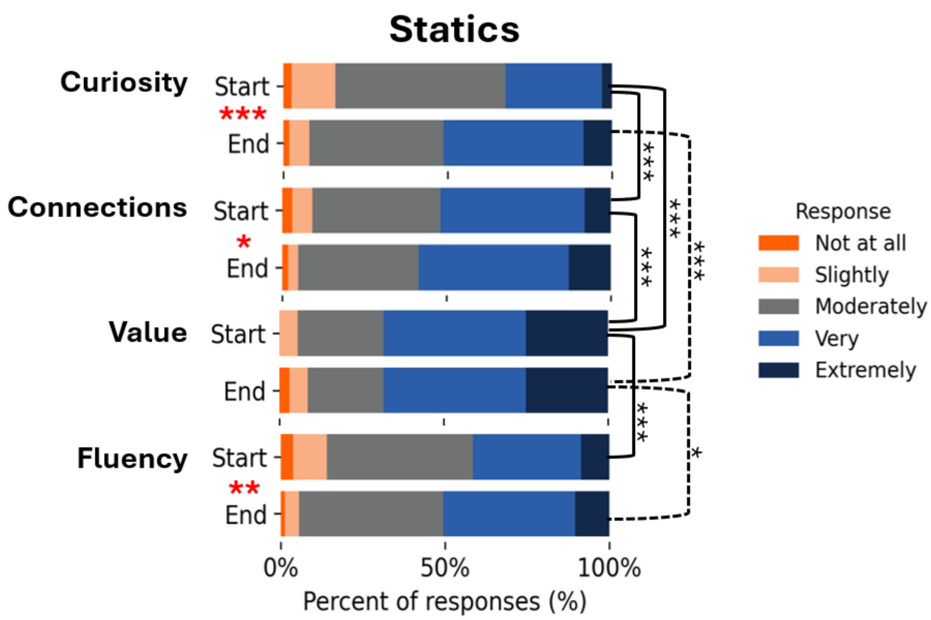

Figure 1: Student responses in Statics at the start and end of the semester. Brackets indicate statistically significant different response distributions between questions (solid at the start and dashed at the end) and red asterisk between start and of the semester for the same question (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$).

In dynamics, at the start of the semester, Creating Value was the only attribute for which responses of “Very” and “Extremely” considerably exceeded 50% of the total (Figure 2). In contrast, Fluency exhibited the least positive distribution, with “Not at all” and “Slightly” responses comprising 15.3% of the total. Fluency increased from the beginning to end of the semester ($p = 0.010$). At the end of the semester, there was a significant difference in response distributions between Fluency and Creating Value ($p = 0.010$), with Creating Value exhibiting more positive responses.

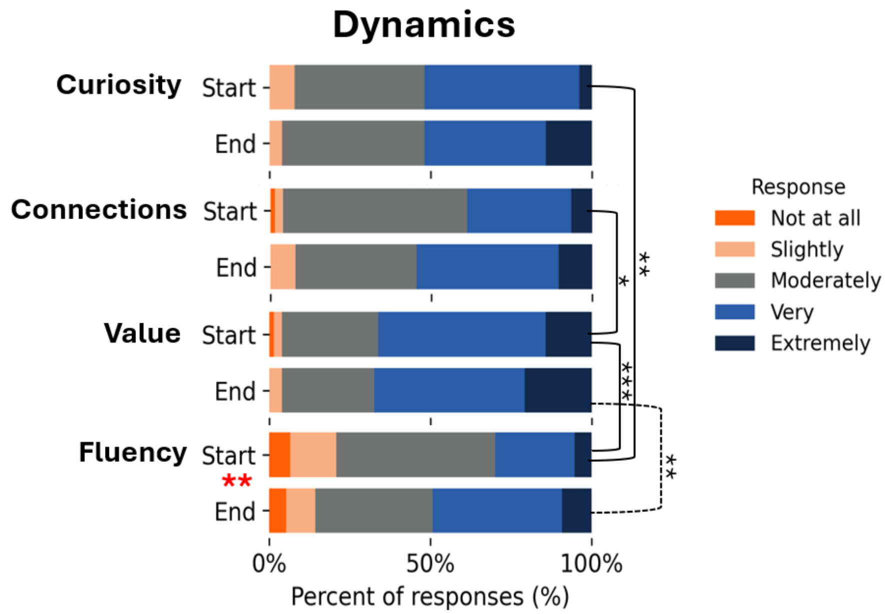

Figure 2: Student responses in Dynamics at the start and end of the semester. Brackets indicate statistically significant different response distributions between questions (solid at the start and dashed at the end) and red asterisk between start and of the semester for the same question (* $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$).

In Solid Mechanics, no significant differences in response distributions were observed between questions at either the start or end of the semester, nor were differences observed between the two time points. However, there were no “Not at all” responses in any question, and the percentage of “Slightly” responses was low (Figure 3).

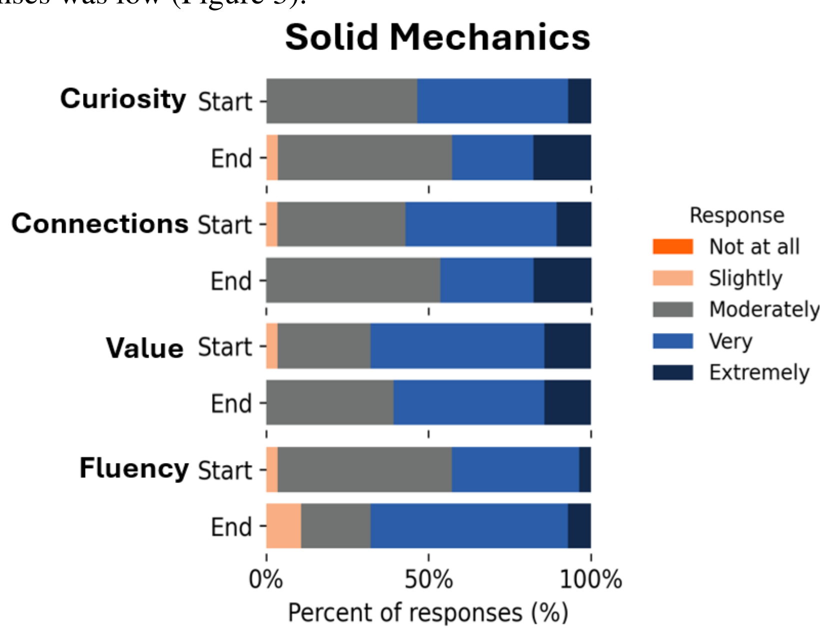

Figure 3: Student responses in Solid Mechanics at the start and end of the semester.

Unit-based EM perception

The most changes from start to end of the semester were observed in Statics, specifically in Curiosity, Connections, and Fluency attributes (Figure 1). Therefore, those questions were explored in depth, looking at unit-specific EM changes (Figure 4, Supplementary Table 3). Details of unit names and topics included are in Supplementary Table 2. For Curiosity, the highest percentage of high positive responses ("Very" + "Extremely") was in unit 7 (moment of inertia & virtual work) with 54.3%, followed by unit 4 (truss, frames, & machines) with 43.3%, and the lowest were units 2 (particle equilibrium & moments) and 6 (centroid, center of gravity & fluid pressure) with 22.9% and 25.6%. The highest percentage of students with some level of disagreement ("Not at all" + "Slightly") was in unit 6 with 39.5%, while the lowest were in units 4 and 7, with 19.7% and 22.9%, respectively.

For Connections, the highest percentage of "Very" and "Extremely" was in unit 1 (position & force vectors) with 53.4%, followed by unit 7 with 44.4%, and the lowest percentage was in unit 6 with 34.9%. The highest percentage of students with some level of disagreement ("Not at all" + "Slightly") was in unit 6 with 23.3%, and the lowest in unit 1 with 8.9%.

For Fluency , the highest percentage of "Very" and "Extremely" was in unit 1 followed by unit 4, with 63.1% and 50.4% respectively, while the lowest were in unit 3 (equivalent systems & rigid body equilibrium), 7 and 6, with 31.5%, 33.3% and 34.1%. The highest percentage of students with some level of disagreement ("Not at all" + "Slightly") was in unit 6, with 38.6%, and the lowest in unit 1, with 9.4%.

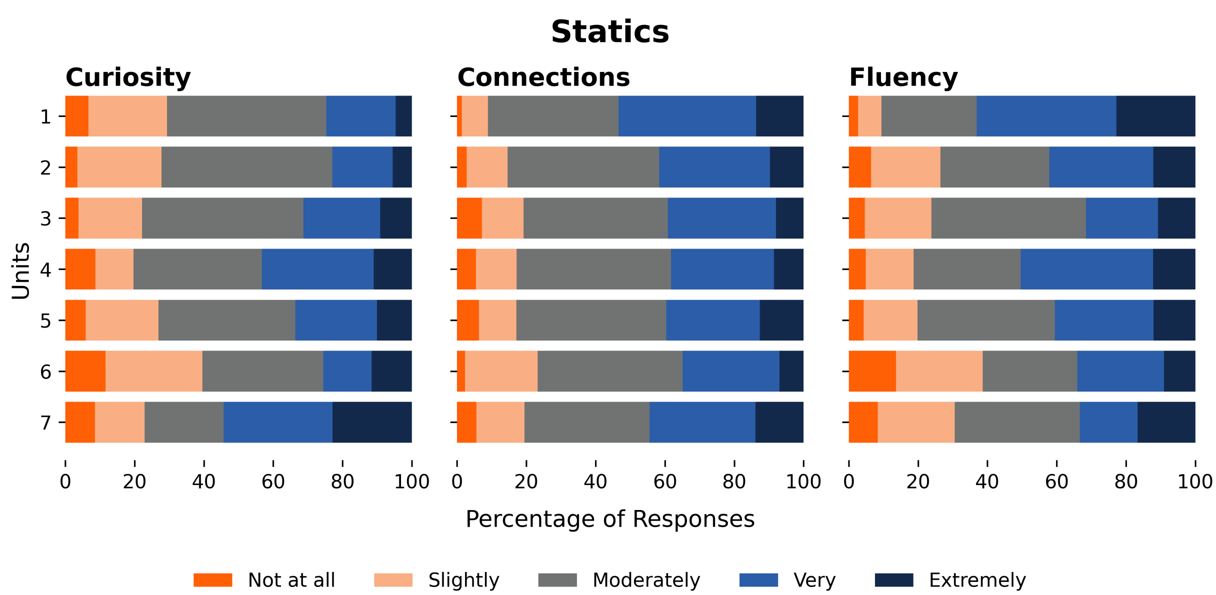

Figure 4: Students perceptions of Curiosity, Connections and Fluency in Statics for each topic-based unit. Unit names and topics are described in Supplemental Table 2 and percentages in Table 3.

In Dynamics, there was a significant difference in Fluency response distribution from start to end of the semester (Figure 2). Furthermore, Fluency in Dynamics was found to be the only attribute to be positively associated with exam performance, close to significance ($p = 0.052$). When looking at Fluency by unit (Figure 5, Supplementary Table 4), the highest percentage of positive perception was in unit 5 (gears & rigid body kinetics, 39.1%) followed by unit 7 (energy, 34.5%), while the lowest was in unit 4 (rigid body kinematics) with 17.4%. The highest percentage of students with the lowest rated responses ("Not at all" + "Slightly") was in unit 2 (vector calculus & rotations) with 57.2% followed by unit 4 with 43.5%, and the lowest in unit 5 with 25.0%. Unit 1 (coordinates & vectors) is not included in this analysis as it is considered to be a content review.

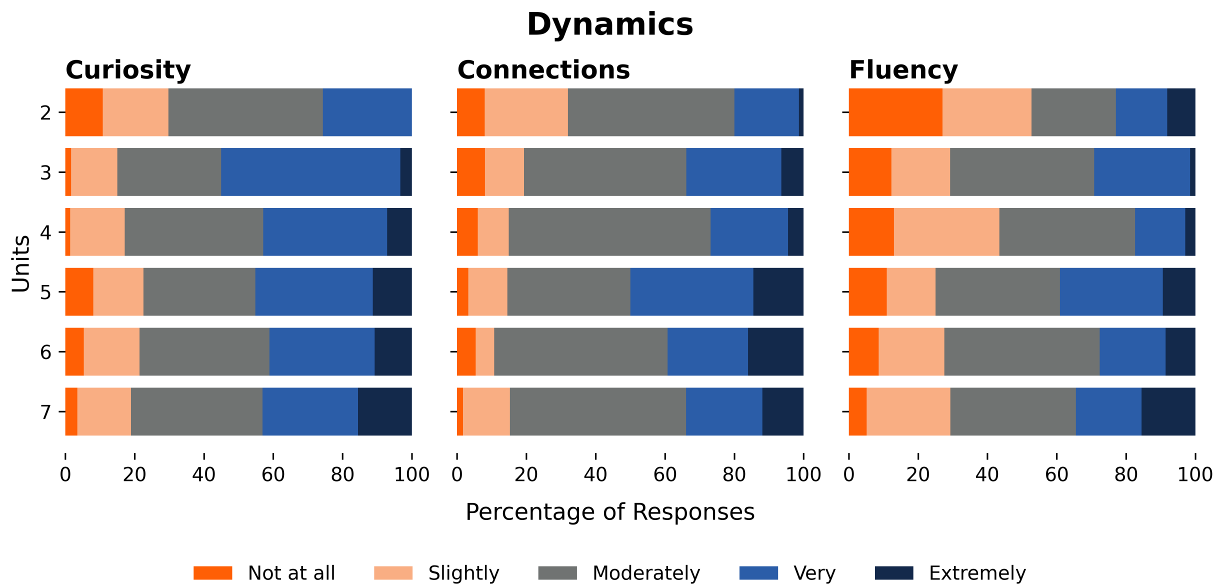

Figure 5: Students perceptions of Curiosity, Connections and Fluency in Dynamics for each topic-based unit. Unit names and topics are described in Supplemental Table 2 and percentages in Table 4.

In Solid Mechanics, there were no significant differences in response distribution from start to end of the semester in any attribute (Figure 3). Therefore unit-specific EM responses were not explored in that course.

Discussion

Across all three courses, students entered the semester with relatively positive perceptions of course content, especially related to the perceived value of the material to their future careers. Creating Value consistently exhibited the highest median response at both the start and end of the semester, suggesting that students broadly recognized the relevance and importance of these courses. In contrast, Curiosity, Connections, and Fluency were initially perceived at more moderate levels. These patterns were consistent across Statics, Dynamics, and Solid Mechanics, despite differences in class size and response rates, suggesting common perceptual trends among students enrolled in these core mechanics courses. Students might have moderately-high EM perceptions at the start of the semester because topics in the first few weeks are less complex and are usually a review from prerequisite courses, leading to increased student familiarity and confidence.

Changes in students' EM perceptions over the semester differed by course. In Statics, Curiosity, Connections, and Fluency positively increased from the start to the end of the semester. In Dynamics, only Fluency exhibited a significant positive shift. In contrast, no significant changes were observed in Solid Mechanics. Because these courses were not explicitly designed to cultivate EM attributes, the relatively small shifts observed from start to end of semester are not unexpected. One possible explanation for the larger changes in Statics (prerequisite for Dynamics and Solid Mechanics) could be the difference in knowledge maturity and general student outlook or academic self-efficacy, as Statics is typically taken by first- or second-year students. We also found that students' academic performance was not strongly correlated to EM. Dynamics was the only course in which Fluency was associated with a higher final exam score. This lack of correlation is also not surprising given the lack of explicit emphasis of EM on course learning objectives and assessment. Therefore, there is an opportunity to develop EM-focused materials that could develop students' EM more explicitly while they also learn core course content.

Although differences in EM perception across units were observable, the magnitude of change from one unit to the next was relatively small. Because the instructional approach remained consistent across units, these results suggest that differences in course topics alone did not substantially influence students' EM perceptions. However, regarding Curiosity, Connections, and Fluency, the weakest units were "centroid, center of gravity, & fluid pressure" in Statics, and "vector calculus & rotations" and "rigid body kinematics" in Dynamics. Designing active-learning strategies and demonstrations that target the most abstract topics in the course could help promote students' EM perceptions.

Although this study presents valuable insights into students' EM perceptions in early engineering courses, there are inherent limitations associated with the use of surveys. Responses were self-reported and voluntary, and may be influenced by student motivation, interpretation of survey items, and response bias. Response rates were small and varied across courses (19.0% in Statics, 31.4% in Dynamics, and 12.7% in Solid Mechanics) which increase the possibility of self-selection bias. Students who completed both surveys (start and end) may have been more engaged or more confident than the overall enrolled population. As a result, findings should be interpreted as representative of participating students rather than the entire course cohorts and indicative of perceived trends rather than direct measures of real behavior. Additionally, logistical issues during survey administration required post hoc reassignment of responses to courses based on timestamps, thus some course misclassifications may remain despite these corrective steps.

As all results are drawn from a single semester, the findings are best interpreted as preliminary evidence contributing to a developing understanding of how students perceive EM within traditional mechanics coursework without any targeted intervention, rather than as definitive conclusions. Future studies of these courses will intentionally integrate EM-focused demonstrations and results from this study will serve as a baseline comparison for future work.

Conclusion

Overall, measured shifts in students' entrepreneurial mindset (EM) perceptions in early engineering mechanics courses with no intentional EM interventions were modest over the course of a single semester. At the same time, the consistently high ratings of perceived value across courses indicate that students broadly appreciate the relevance of mechanics. Given that this study reflects a single semester and relies on voluntary self-reported survey data, the findings should be interpreted as preliminary. They serve primarily as a baseline for understanding how students perceive Curiosity, Connections, Fluency, and Creating Value in mechanics courses that are not explicitly designed to cultivate entrepreneurial mindset attributes, rather than evidence of strong instructional effects. Future offerings of these courses will intentionally incorporate and evaluate the impact of targeted EM interventions in the identified weaker units. Physical demonstrations, such as an instrumented skateboard or a trebuchet, will be developed to connect abstract course concepts to real-world applications across Statics, Dynamics, and Solid Mechanics.

Acknowledgments

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Supplemental Material

Table 2: Summary of TAM 2XX units and topics covered in Fall 2025

Unit	TAM 210 (Statics)	TAM 212 (Dynamics)	TAM 251 (Solid Mechanics)
1	Position & Force vectors • Force vectors • Position vectors • Vector operations	Coordinates & Vectors • Positions and vectors • Polar coordinate system • Basis vectors • Vector projections	Stress & Strain • Equilibrium and stress • Normal and shear stress • Stress design and strain
2	Particle Equilibrium & Moments • Particles and systems at equilibrium • Moment vectors • Couple moments	Vector calculus & Rotations • Vector derivatives • Velocity and acceleration in polar basis • Vector integration • Angular velocity and acceleration • Solving equations	Material Properties & Axial loading • Stress-strain diagram • Deformations • Indeterminate structures • Temperature effects • Misfit problems
3	Equivalent systems & Rigid body equilibrium • Equivalent systems • Distributed loads • Constraints • Reaction forces • Rigid body equilibrium	TN basis & Particle kinetics • Tangent normal basis • Particle kinetics • Numerical integration	Torsion • Torsion • Torque-displacement relation • Indeterminate shafts
4	Truss, Frames & Machines • Trusses • Frames • Machines	Rigid body kinematics • Rigid body velocity • Constrained motion • Rigid body acceleration	Beams in bending • SF and BM diagrams • Beams in bending • Normal stress • Composite beams
5	Internal forces & Friction • All previous topics • Shear • Bending moment diagrams • Friction	Gears & Rigid body kinetics • Gears • Center of mass • Mass moment of inertia • Rigid body kinetics	Transverse shear stress • Transverse shear • Shear flow
6	Centroid, Center of gravity & Fluid pressure • Centroids • Fluid pressure	Rolling • Instantaneous center • Rolling without slip	Combined loading • Pressure vessels • Combined loading
7	MOI & Virtual work • Moment of inertia • Virtual work	Energy • Work and energy • Momentum • Friction	Stress transformation • Stress transformation • Theories of failure

Table 3: Percentage (%) of students' answers to Q1: Curiosity, Q2: Connections and Q4: Fluency in Statics for each topic-based unit. Unit names and topics are described in Supplemental Table 2.

Statics	Unit	Not at all (1)	Slightly (2)	Moderately (3)	Very (4)	Extremely (5)
Curiosity	1	6.7	22.7	40.6	20.0	4.7
	2	3.5	24.3	49.3	17.4	5.6
	3	3.8	18.3	46.6	22.1	9.2
	4	8.7	11.0	37.0	32.3	11.0
	5	5.9	21.0	39.5	23.5	10.1
	6	11.6	27.9	34.9	14.0	11.6
	7	8.6	14.3	22.9	31.4	22.9
Connections	1	1.4	7.5	37.7	39.7	13.7
	2	2.8	11.8	43.8	31.9	9.7
	3	7.2	12.0	41.6	31.2	8.0
	4	5.5	11.7	44.5	29.7	8.6
	5	6.3	10.8	43.2	27.0	12.6
	6	2.3	20.9	41.9	27.9	7.0
	7	5.6	13.9	36.1	30.6	13.9
Fluency	1	2.7	6.7	27.5	40.3	22.8
	2	6.4	20.0	31.4	30.0	12.1
	3	4.6	19.2	44.6	20.8	10.8
	4	4.9	13.8	30.9	38.2	12.2
	5	4.3	15.5	39.7	28.4	12.1
	6	13.6	25.0	27.3	25.0	9.1
	7	8.3	22.2	36.1	16.7	16.7

Table 4: Percentage (%) of students' answers to Q1: Curiosity, Q2: Connections and Q4: Fluency in Dynamics for each topic-based unit. Unit names and topics are described in Supplemental Table 2. Unit 1 is not included as it is a review of Vectors.

Dynamics	Unit	Not at all (1)	Slightly (2)	Moderately (3)	Very (4)	Extremely (5)
Curiosity	2	10.8	18.9	44.6	25.7	0.0
	3	1.7	13.3	30.0	51.7	3.3
	4	1.4	15.7	40.0	35.7	7.1
	5	8.1	14.5	32.3	33.9	11.3
	6	5.4	16.1	37.5	30.4	10.7
	7	3.5	15.5	37.9	27.6	15.5
Connections	2	8.0	24.0	48.0	18.7	1.3
	3	8.1	11.3	46.8	27.4	6.5
	4	6.0	9.0	58.2	22.4	4.5
	5	3.2	11.3	35.5	35.5	14.5
	6	5.4	5.4	50.0	23.2	16.1
	7	1.7	13.6	50.9	22.0	11.9
Fluency	2	27.0	25.7	24.3	14.9	8.1
	3	12.3	16.9	41.5	27.7	1.5
	4	13.0	30.4	39.1	14.5	2.9
	5	10.9	14.1	35.9	29.7	9.4
	6	8.6	19.0	44.8	19.0	8.6
	7	5.2	24.1	36.2	19.0	15.5