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Assessment of Student Mindset and Learning Strategy in a Mastery-Based Learning Statics Course

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Abstract

Statics is a course taken by all undergraduate students who are pursuing an engineering degree at our institution. It effectively unlocks the rest of the mechanical engineering curriculum, serving as a pre-requisite for subsequent core curriculum courses. Based on instructor observations, many students perceive Statics to be the first challenging engineering course they encounter, and it is not uncommon for students to voice difficulty adjusting to the rigorous coursework. Additionally, an increasing number of students face barriers due to a lack of pre-requisite knowledge. Instructor observations also suggest that traditional grading systems that rely on partial credit result in students focused on short-term rewards (e.g., a good grade on a single assignment) instead of long-term knowledge gains. In response to these observations, the course instructor updated Statics to follow a mastery-based learning format. This teaching approach places emphasis on whether students learn material by the end of the course instead of when, thereby encouraging students to reflect on their own learning. The Motivated Strategies for Learning Questionnaire (MSLQ) is a validated, widely used assessment tool that provides a quantitative assessment of five factors pertaining to student motivation and learning strategies: self-efficacy, intrinsic value, test anxiety, cognitive strategy use, and self-regulation. The MSLQ was distributed to Statics students at three timepoints (beginning, middle, and post-course). Scores were calculated at each timepoint and compared using a repeated measures ANOVA and Pearson's r. Significant differences were identified with post-hoc analysis.

Introduction

Mastery-based learning (MBL) is an alternative grading approach that provides students with flexibility to learn course content at their own pace. It focuses on students demonstrating they have met learning objectives by the end of a course but does not place importance on when they demonstrate their knowledge during the academic term. While there is no partial credit, students have multiple opportunities for practice, feedback, and reassessment. Benefits of MBL include promoting deep foundational understanding, normalizing failure, and encouraging students to learn from mistakes [1]. Furthermore, research has shown that students who are given mastery goals concentrate on achieving competency and demonstrate a high level of self-motivation in their pursuit of deeper learning [2].

Based on these advantages, a MBL structure was piloted in our institution's Statics course in Fall 2024 to intentionally foster a learning environment aligned with students taking ownership of their own learning, persevering despite setbacks, and valuing continuous improvement. Implementing this new structure was also due in part to our institution's efforts to instill students with the entrepreneurial mindset (EM), as outlined by the Kern Entrepreneurial Engineering Network (KEEN). KEEN characterizes EM as a collection of attitudes and behaviors that empower engineers to solve problems innovatively, think adaptively, and create meaningful value [3]. While EM encompasses several interconnected principles, our MBL implementation focused heavily on the role of learning from failure as a pathway to curiosity, connection-building, and value creation. The mastery approach provided a natural environment for this emphasis, allowing students to repeatedly engage with challenging concepts in ways that normalized iteration and encouraged reflective growth rather than one-time performance.

Given that the Statics MBL implementation structure was the first of its kind in our engineering curriculum, we wanted to gain insight into our students' mindsets in this newly introduced learning environment. The Motivated Strategies for Learning Questionnaire (MSLQ) is one of many tools for assessment of student attitude and approach towards learning. More specifically, this validated tool provides measures of motivational and self-regulated learning components of student performance within a specific context (e.g., course, task, etc.) [4]. The questionnaire's motivational components encompass the reasoning behind a student's engagement with a specific task and reflect a set of three motivational constructs: expectancy (students' attitudes towards accomplishing a given task), value (the reasoning behind students' engagement), and affect (students' emotionality, namely their level of anxiety, worry and concern as it relates to testing) [5]–[7]. The questionnaire's self-regulated learning components focus on students' choice of methods and strategies to accomplish a given task and reflect a second set of constructs: cognitive strategy use, metacognitive strategy use, and management and control of effort [5]–[7].

The MSLQ can be administered using one of two versions (44-item or 81-item). The 44-item version captures three motivational components (also referred to as motivational factors). The first motivational factor subscale, self-efficacy, is a malleable and context specific construct that broadly refers to an individual's self-perception of their own ability to successfully complete a task [8], [9]. In educational contexts, self-efficacy refers to a student's self-perception of their own ability to guide and control their academic achievement [10], [11]. Influential predictors of high self-efficacy include previous experiences of success based on one's own efforts, observations of others successfully completing tasks, and receival of encouragement from others [8], [9]. The second motivational factor subscale, intrinsic value, captures the level to which students perceive what they are learning to be meaningful, interesting, and worthwhile. Test anxiety, the third motivational factor subscale, assesses students' emotional reactions to a task and reflects the affective component, not the cognitive component, of test anxiety [12].

Unsurprisingly, interconnections between the MSLQ's motivational components are well-demonstrated. In post-secondary settings, students with higher self-efficacy are more likely than their peers to persist and overcome challenges [5], [13], attain a high level of academic achievement [13]–[15], believe that intelligence is malleable and can change [11], [16], adopt mastery goals [16], and demonstrate an intrinsic interest to learn [14], [15]. Conversely, those with lower levels of self-efficacy often exhibit higher levels of anxiety and stress [8], [9].

In addition to the three motivational components, the 44-item MSLQ captures two self-regulated learning strategy factors. The first, cognitive strategy use, measures the degree to which students use specific learning strategies, namely rehearsal, elaboration, and organization. The second, self-regulation, assesses students' ability to self-reflect on their learning and persist through challenges. Because self-regulated learning is context dependent, the MSLQ does not use norms, but specifically instructs students to provide responses based on their experience in a specific course [12].

There are several key differences between the 44-item and 81-item versions of the MSLQ. As previously described, the 44-item MSLQ incorporates five factor subscales and takes about 10-20 minutes to complete. The 81-item MSLQ is divided into fifteen factor subscales and takes about 20-30 minutes to complete. One benefit of the 81-item MSLQ is that its factor subscales provide more detailed insights into the motivational and self-regulated learning constructs. Expectancy, for example, is broken down into self-efficacy (i.e., confidence in one's ability to perform a given task successfully) and control beliefs (i.e., confidence that one's own efforts, not external factors, will result in a positive outcome). Similarly, value is broken down into intrinsic goal orientation (i.e., motivation driven by internal factors, e.g., curiosity), extrinsic goal orientation (i.e., motivation driven by external factors, e.g., grades or instructor approval), and task value beliefs (i.e., motivation driven by the perceived usefulness, importance, or interest of course content). One disadvantage to the 81-item version is that it takes approximately twice as long as the short version to complete. Thus, while the 81-item MSLQ provides more granular information on motivational and self-regulated learning constructs, it also faces increased vulnerability to survey fatigue which can reduce the accuracy of results [17]. Regardless of the version researchers choose to implement, MSLQ scale scores can be evaluated in conjunction with or independently from one another [5], [12].

The MSLQ has been used extensively in educational research and in a variety of disciplinary, cultural, and linguistic contexts [5]–[7], [18], [19]. Similarly, its application to undergraduate engineering education contexts is not new [20]–[22]. Examples include exploration of correlations between engineering student self-efficacy and retention [23], test anxiety and GPA [24], and intrinsic goal orientation and academic performance [25].

For the purposes of this study, we implemented the 44-item MSLQ to assess student motivation and self-regulated learning components in an undergraduate engineering MBL course. More specifically, we aimed to address the following research questions:

(1) How do students' MSLQ scale scores change over the course of a 10-week MBL structured Statics course?
(2) What correlations exist between the MSLQ scales?

Methods

Course Structure

The Statics course content was divided into thirteen distinct skills categorized into three levels of increasing complexity. Students had weekly opportunities to demonstrate mastery of these skills by completing quiz questions with perfect or near-perfect solutions. For example, minor algebra mistakes were considered acceptable. Student quizzes were evaluated as "Met" or "Not Yet" and final course grades were determined by the number of skills students successfully met by the end of the academic term.

Throughout the 10-week course, the instructor encouraged students to self-reflect and learn from their mistakes both during lectures and office hours but did not give formal assignments to specifically address these behaviors. Similarly, there were not additional activities or assignments beyond the MBL structure to guide students to develop higher scores on the MSLQ.

Motivated Strategies for Learning Questionnaire (MSLQ)

The course instructor distributed the 44-item MSLQ via an online Qualtrics survey at three prescribed timepoints throughout the course: (1) after the first testing opportunity (Week 2); (2) after multiple testing opportunities (Week 8); and (3) after the final testing opportunity, but before final course grades were released (post-course). Students self-rated each questionnaire item on a standard 7-point Likert scale (1 = not at all true of me, 7 = very true of me) and were instructed to provide responses as they related to the Statics course (Appendix 1). Since the survey was administered three times over the course of 10 weeks, we elected to use the 44-item MSLQ to avoid survey fatigue. The surveys were required participation assignments; however, a student's responses were analyzed only if they agreed to participate in the IRB-approved study. Survey responses were deidentified by a faculty member who was not the course instructor. This same faculty member sent deidentified responses to the course instructor for analysis after final course grades were posted.

A total of 83 students were enrolled in the course. 60 students agreed to participate, 44 of whom responded to the survey at all three timepoints (55% overall participation rate). We considered study participants to be overall representative of the entire cohort based on the average number of skills successfully passed by the end of the course (study participants: 9.93 ± 3.01, entire cohort: 9.04 ± 3.35).

Data Analysis

MSLQ scale scores were calculated in MATLAB (R2023a, Mathworks Inc., Natick MA, USA) by averaging the item scores for each of the five factor subscales. Ratings for negatively worded items were reversed prior to computing average scale scores so that all item scores reflected positive wording (see Appendix 1). Thus, higher factor subscale scores represent a higher level of that given factor. All other data analysis was completed in IBM SPSS Statistics (v30).

Differences in mean scale scores were compared using descriptive statistics and a repeated measures analysis of variance (ANOVA) was applied to test within-subjects effects. Repeated measures ANOVA assumes equal variances of differences across groups and violation of this assumption can affect the test's reliability, mainly in the form of Type I errors (false positives, i.e., incorrectly rejecting the null hypothesis). If the assumption of equal variances is violated, a correction must be applied to ensure validity of the repeated measures ANOVA result. To address this concern, we applied Mauchly's Test to check the assumption of equal variance. The assumption was met for all factors apart from self-efficacy and a Huynh-Feldt correction was applied in this case (Table 1). A post-hoc analysis with Bonferroni corrections for multiple comparisons was used to analyze significant differences between means. Linear correlations between individual factor subscale scores were evaluated with a Pearson's r (two-tailed). Significance level was set to 0.05 for all tests (ANOVA, Mauchly's, Pearson correlation coefficient).

Results

Differences in MSLQ Scale Scores

Results of the repeated measures ANOVA indicate significant within-subject effects for the self-efficacy ($p < 0.001$), intrinsic value ($p < 0.001$), and self-regulation ($p < 0.02$) factors (Table 1). No significant within-subject effects were found for test anxiety or cognitive strategy use.

Post-hoc analysis (Figure 1) revealed significant increases in self-efficacy and intrinsic value scale scores from Week 2 to post-course ($p < 0.01$) and from Week 8 to post-course ($p < 0.001$). A significant decrease in self-regulation was found from Week 2 to post-course ($p < 0.05$), but no significant change was found from Week 8 to post-course. There were no significant changes between Weeks 2 and 8 for any of the MSLQ factor scales.

Table 1. Mauchly's Test and repeated measures ANOVA results for each MSLQ factor. Significance level was set to 0.05.

MSLQ Sub-Scale Factor	Mauchly's Test[a] (Equal Variance Assumption)	Repeated measures ANOVA (Within-Subjects Effects)
Self-Efficacy (SE)	$p = 0.042$[b]	$p < 0.001$
Intrinsic Value (IV)	$p = 0.083$	$p < 0.001$
Test Anxiety (TA)	$p = 0.243$	n.s.
Cognitive Strategy Use (CS)	$p = 0.200$	n.s.
Self-Regulated (SR)	$p = 0.734$	$p < 0.02$

[a] $p > 0.05$ indicates the assumption of equal variance is met. $p < 0.05$ indicates the assumption is violated and a correction is required. [b] Huynh-Feldt correction applied.

Correlations between MSLQ Scale Scores (Table 2)

At Week 2, higher levels of self-efficacy were correlated with higher levels of intrinsic value and lower levels of test anxiety ($r = .690$, $p < 0.01$ and $r = – .479$, $p < 0.01$, respectively). Similar correlations were found at Week 8 (self-efficacy and intrinsic value: $r = .600$, $p < 0.01$; self-efficacy and test anxiety: $r = – .442$, $p < 0.01$) and post-course, albeit to a lesser degree (self-efficacy and intrinsic value: $r = .475$, $p < 0.01$; self-efficacy and test anxiety: $r = – .358$, $p < 0.01$).

The only significant correlation between a MSLQ motivational component factor and learning strategy component factor was found at Week 8, where higher levels of cognitive strategy use were correlated with higher levels of intrinsic value ($r = .396$, $p < 0.01$). Higher levels of cognitive strategy use were also correlated with higher levels of self-regulation at this same timepoint ($r = .407$, $p < 0.01$).

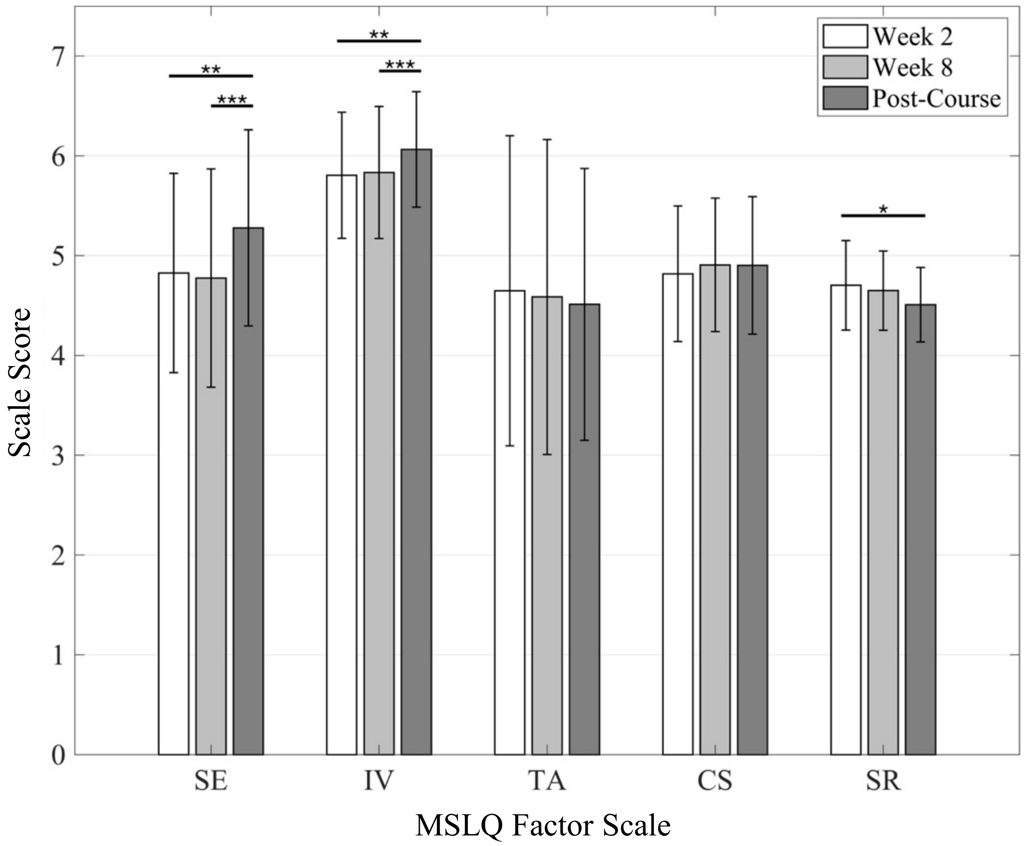

Figure 1. Mean MSLQ scale scores at Week 2, Week 8, and post-course. Error bars indicate standard deviations around the mean. Mean and standard deviation values are shown in Table 2. Higher scores indicate a higher presence of the factor. SE = Self-Efficacy, IV = Intrinsic Value, TA = Test Anxiety, CS = Cognitive Strategy Use, SR = Self-Regulation. *Indicates significant at the 0.05 level; **Indicates significant at the 0.01 level; ***Indicates significance at the 0.001 level.

Discussion

This study analyzes student MSLQ responses collected at three timepoints during an MBL structured Statics course to gain an improved understanding of students' motivational beliefs and learning strategies and the interplay between them. Results revealed average scale scores greater than 4 for every factor at every timepoint, indicating an overall tendency towards self-reported presence of all factors (4 = neutral on a 7-pt Likert scale, see Appendix 1).

Results show that student self-efficacy was significantly higher post-course than in Week 2, indicating an overall increase in students' confidence in their abilities to succeed based on their own efforts and the mean post-course score was consistent with previous reports in the literature [25]. Interestingly, comparison of Weeks 2 and 8 suggests students may have temporarily doubted their abilities, as evidenced by a slight but non-significant decrease in self-efficacy between these two timepoints. While not significant, this decrease aligns with the notion that when students enter a course, their initial self-efficacy is based on experiences outside of the current course specific context and subsequently, as time progresses, their self-efficacy is shaped by their course-specific experiences and performance [26]. Since self-efficacy is directly

Table 2. Factor correlations at Week 2, Week 8, and post-course. *Indicates significant at the 0.05 level; **Indicates significant at the 0.01 level. SE = Self-Efficacy, IV = Intrinsic Value, TA = Test Anxiety, CS = Cognitive Strategy Use, SR = Self-Regulation.

	Factor	SE	IV	TA	CS	SR
Week 2	SE	—	**.690****	**– .479****	.097	– .111
	IV		—	– .282	.152	.070
	TA			—	.190	.127
	CS				—	.170
	SR					—
	Mean ± *SD*	4.83 ± 1.00	5.81 ± 0.63	4.65 ± 1.55	4.82 ± 0.68	4.70 ± 0.45
Week 8	*Factor*	SE	IV	TA	CS	SR
	SE	—	**.600****	**– .442****	.244	.093
	IV		—	– .031	**.396****	.098
	TA			—	.243	– .117
	CS				—	**.407****
	SR					—
	Mean ± *SD*	4.78 ± 1.09	5.83 ± 0.66	4.59 ± 1.58	4.91 ± 0.67	4.65 ± 0.40
Post-Course	*Factor*	SE	IV	TA	CS	SR
	SE	—	**.475****	**– .358***	.102	.001
	IV		—	.194	.214	.213
	TA			—	.271	.149
	CS				—	.234
	SR					—
	Mean ± *SD*	5.28 ± 0.98	6.06 ± 0.58	4.51 ± 1.36	4.90 ± 0.69	4.51 ± 0.37

influenced by perception of progress (or lack thereof), the small decrease at Week 8 could reflect students feeling uncertain about the implications of their lack of progress towards mastery. Unfortunately, we are unable to confirm this theory under our IRB approved protocol.

Significant increases in intrinsic value were seen from Week 2 to post-course and from Week 8 to post-course. These increases perhaps indicate that students' perceptions of the importance of what they were learning increased towards the latter part of the course. Intrinsic value is a broad construct, however. It extends beyond task value and encompasses orientation toward challenges, curiosity, enjoyment, interest, and perceived value of work. Therefore, the observed increases in intrinsic value could instead allude to an increased desire for learning driven by internal factors. While the 44-item MSLQ does not distinguish between these interpretations, the 81-item version could be used to do so. There was a consistent, positive correlation between intrinsic value and self-efficacy at all timepoints, alluding to a strong link between these factors.

Mean test anxiety scores were consistently between 4 (neither true or untrue of me) and 5 (somewhat true of me). These values are consistent with those of other engineering education studies [27]. While we found no significant changes in test anxiety, there was a significant negative correlation between test-anxiety and self-efficacy at all three timepoints, a result that also aligns with previously reported trends [28], [29]. This finding implies that students continued to experience the same level of anxiety despite increased beliefs in their abilities. As higher educators continue to see a growing number of anxious students in our classrooms [30]–[34], understanding the interplay between test anxiety and self-efficacy will become increasingly important, especially given the malleability of self-efficacy.

Results showed no significant changes in cognitive strategy use. This finding indicates that students did not change their learning methodology or approach as the course progressed, regardless of their academic performance. Enhanced cognitive strategy use (i.e., use of deeper learning strategies) was significantly correlated with enhanced self-regulation and intrinsic value at Week 8, however. This correlation between intrinsic value and cognitive strategy use was the only significant correlation found between motivational and learning strategy components across all three timepoints. This finding contradicts the initial findings of Pintrich et al., who found that both self-efficacy and intrinsic value were positively correlated with cognitive strategy use [5]. One possible explanation for this discrepancy is that the 44-item MSLQ statements may not resonate with the learning methods employed by engineering students (e.g., "When I study for a test I practice saying the important facts over and over to myself" or "When I read materials for this class, I say the words over and over to myself to help me remember"). Another possible explanation could be the inherent difference between the populations reflected in the two studies (undergraduate engineering students vs. seventh grade students).

There was a significant decrease in self-regulation from Week 2 to post-course, meaning that despite improved self-efficacy and perceived value, students had diminished ability to self-reflect on their learning and persevere through challenges. This result could be due to students feeling overwhelmed with balancing coursework towards the end of the academic term, leaving little room for retrospection. However, based on this study's data alone, there is no way of knowing whether this finding was specific to the current Statics course or was broader in scope across multiple contexts. Given the importance of student self-reflection on learning, educators should consider ways to help their students practice this habit throughout the entirety of an academic term.

This study has several limitations. First, MSLQ data were not collected from previous cohorts prior to the class being moved to a MBL format. Therefore, the results presented here are confined to trends within a single cohort. Second, students' progress in skill mastery was not linked to their MSLQ responses. Because MBL provides students with autonomy to choose their level of dedication and persistence towards mastery, future work should incorporate a quantitative metric that links students' MSLQ scores to course progress (i.e., number of quizzes passed) to investigate potential correlations between progress in skill mastery and MSLQ scale scores. Third, the findings of this study are based on self-reported learning behaviors and therefore rely on students' abilities to provide responses that accurately reflect reality. We utilized the 44-item MSLQ, but it is still possible that students' responses were impacted by survey fatigue and boredom. Lastly, this study did not collect qualitative data to support the quantitative findings. Future work should incorporate open-ended survey questions and qualitative analysis to explore the reasonings behind meaningful and significant MSLQ scale correlations.

Conclusions and Potential Future Work

We identified significant changes in and correlations between a subset of motivational beliefs and self-regulated learning strategies, as measured by the 44-item MSLQ, as students progressed through our 10-week MBL structured Statics course. It will be interesting to see if incorporating intentional interventions designed to target those aspects of student mindset will have an impact on these outcomes. Additionally, since student mindset fluctuates based on setting, it could prove beneficial to implement alternative assessment tools and explore how students' motivational beliefs and learning strategies vary across multiple contexts (e.g., an entire curriculum).

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Appendix 1. MSLQ Instrument [5]

Likert Scale Ratings

The 44-item MSLQ survey was distributed to students via an online Qualtrics survey. Students selected one of the following ratings for each item: 1 = Very untrue of me, 2 = Untrue of me, 3 = Somewhat untrue of me, 4 = Neither true or untrue of me, 5 = Somewhat true of me, 6 = True of me, 7 = Very true of me. To ensure complete capture of responses, the survey was set-up to force responses to every item.

Qualtrics Survey

Instructions:

- Please rate the following items based on your behavior in Statics.
- Your rating should be on a 7-point scale where **1 = not at all true of me** to **7 = very true of me.**

1. I prefer class work that is challenging so I can learn new things.
2. Compared with other students in this class I expect to do well.
3. I am so nervous during a test that I cannot remember facts I have learned.
4. It is important for me to learn what is being taught in this class.
5. I like what I am learning in this class.
6. I'm certain I can understand the ideas taught in this course.
7. I think I will be able to use what I learn in this class in other classes.
8. I expect to do very well in this class.
9. Compared with others in this class, I think I'm a good student.
10. I often choose practice problems I will learn something from even if they require more work.
11. I am sure I can do an excellent job on the problems and tasks assigned for this class.
12. I have an uneasy, upset feeling when I take a test.
13. I think I will receive a good grade in this class.
14. Even when I do poorly on a test I try to learn from my mistakes.
15. I think that what I am learning in this class is useful for me to know.
16. My study skills are excellent compared with others in this class.
17. I think that what we are learning in this class is interesting.
18. Compared with other students in this class I think I know a great deal about the subject.
19. I know that I will be able to learn the material for this class.
20. I worry a great deal about tests.
21. Understanding this subject is important to me.
22. When I take a test I think about how poorly I am doing.
23. When I study for a test, I try to put together the information from class and from the textbook.
24. When I do practice problems, I try to remember what the teacher said in class so I can answer the questions correctly.
25. I ask myself questions to make sure I know the material I have been studying.
26. It is hard for me to decide what the main ideas are in what I read.

27. When work is hard I either give up or study only the easy parts.
28. When I study I put important ideas into my own words.
29. I always try to understand what the teacher is saying even if it doesn't make sense.
30. When I study for a test I try to remember as many facts as I can.
31. When studying, I copy my notes over to help me remember material.
32. I work on practice problems and answer end of chapter questions even when I don't have to.
33. Even when study materials are dull and uninteresting, I keep working until I finish.
34. When I study for a test I practice saying the important facts over and over to myself.
35. Before I begin studying I think about the things I will need to do to learn.
36. I use what I have learned from old practice problem sets and the textbook to do new assignments.
37. I often find that I have been reading for class but don't know what it is all about.
38. I find that when the teacher is talking I think of other things and don't really listen to what is being said.
39. When I am studying a topic, I try to make everything fit together.
40. When I'm reading I stop once in a while and go over what I have read.
41. When I read materials for this class, I say the words over and over to myself to help me remember.
42. I outline the chapters in my textbook to help me study.
43. I work hard to get a good grade even when I don't like a class.
44. When reading I try to connect the things I am reading about with what I already know.

Scoring

MSLQ scale scores were calculated by averaging the ratings for corresponding items (Table 3).

Table 3. Mapping between MSLQ items and scales. *indicates reversed item score. For example, a high score on item 27, *When work is hard I either give up or study only the easy parts*, corresponds to a lower level of self-regulation.

	MSLQ Scale	**Corresponding Items**
Motivational Beliefs	Self-Efficacy	2, 8, 9, 11, 13, 16, 18, 19
	Intrinsic Value	1, 4, 5, 7, 10, 14, 15, 17, 21
	Test Anxiety	3, 12, 20, 22
Self-Regulated Learning Strategies	Cognitive Strategy Use	23, 24, 26*, 28, 29, 30, 31, 34, 36, 39, 41, 42, 44
	Self-Regulation	25, 27*, 32, 33, 35, 37*, 38*, 40, 43

Minor Adjustments from Original MSLQ

Some item wording was slightly adjusted to better reflect STEM context and course terminology (e.g., practice problems vs. homework, textbook vs. book, etc.). The original MSLQ wording for these items is provided below:

- Item 10: I often choose paper topics I will learn something from even if they require more work.

- Item 23: When I study for a test, I try to put together the information from class and from the book.
- Item 24: When I do homework, I try to remember what the teacher said in class so I can answer the questions correctly.
- Item 32: I work on practice exercises and answer end of chapter questions even when I don't have to.
- Item 36: I use what I have learned from old homework assignments and the textbook to do new assignments.
- Item 42: I outline the chapters in my book to help me study.