

MBL (Mastery-Based Learning) Supports a Normalization of Failure as an Essential Part of Learning

Dr. Kurt M. DeGoede, Elizabethtown College

Professor of Engineering and Physics, Elizabethtown College. His research interests in biomechanics include developing clinical instruments for rehabilitation and human performance. Dr. DeGoede teaches upper-level undergraduate mechanical engineering using mastery-based assessment models and project-based learning, design courses, and first-year multidisciplinary courses.

Dr. Brenda Read-Daily, Elizabethtown College

Dr. Brenda Read-Daily is an Associate Professor of Engineering at Elizabethtown College in Pennsylvania. She holds a BS in Civil Engineering from Bradley University, and a MS and PhD in Environmental Engineering from the University of Notre Dame.

Dr. Rachel Koh, Smith College

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Abstract

The positive benefits of fostering a Growth Mindset in students have been widely reported. Developing the skill of persisting through and learning from failure is key to developing a growth mindset and the entrepreneurial mindset – KEEN (Kern Entrepreneurial Engineering Network). This work-in-progress paper will examine how an MBL model could be a valuable tool for developing our students' Failure Mindset. The MBL framework we employ is centered on learning through practice and coaching – making mistakes and learning from those mistakes, frequent low-stakes assessments, analyzing the results for further practice, and coaching on that skill before moving forward to the next skill. A positive Failure Mindset looks at failure as a positive outcome that enhances one's opportunities for learning. In this study, we will explore preliminary data by examining three groups of engineering students:

- entering first-year students including those enrolled in an MBL course and those not enrolled in this course,
- third-year students enrolled in an MBL course – 90% of these students have previously taken at least one MBL course,
- and students enrolled in a one-semester off-campus alternative MBL-assessed project-based learning curriculum.

We will use an established tool for assessing Failure Mindset and test the following hypotheses.

- H1 At initial assessment, third-year students will exhibit a higher propensity toward a positive Failure Mindset than the entering first-year students.
- H2 The measure of Failure Mindset will increase over the semester for all three groups of students.
- H3 The first-year students in the MBL course will exhibit a more positive Failure Mindset at the end of the semester than those not enrolled in an MBL course.

We will also examine any correlation between a Failure Mindset and course performance.

Introduction

The positive benefits of fostering a Growth Mindset in our students have been widely reported [1]. In our engineering curriculum, we hope to train our students to develop the skill of persisting through and learning from failure [2]. This is a key skill in developing the Entrepreneurial Mindset, as framed by Kern Entrepreneurial Engineering Network (KEEN) [3]. As part of the KEEN, we have realized that our Mastery-Based Assessment model could be an important tool for developing our students' Failure Mindset [4]. We defined a positive Failure Mindset as one that looks at failure as a positive outcome that enhances one's opportunities for learning. In this study, we explored a more focused study of our students' Failure Mindset and changes observed during MBL courses. We studied two groups of engineering students:

- entering first-year students enrolled in PHY120 and
- third-year students enrolled in EGR360.

We also collected partial data from a smaller group of first-year engineering students not enrolled in PHY120 and four students enrolled in a pilot immersive project-based learning semester.

Introductory Mathematics for Physics and Engineering (PHY120) is a mathematics course that prepares students for the quantitative analysis conducted in later engineering courses. It also serves as a refresher of mathematical topics from high school such as algebra, logarithms, and trigonometry better preparing students to be successful in the calculus sequence. The course is taken primarily by first-year, first-semester students with an intended engineering major and is assessed with an MBL framework.

Dynamics (EGR 360) is a junior-level engineering science focused on planar dynamics of rigid bodies. The course is taught using an MBL framework similar to the approach used in PHY120.

It was assumed the majority of the PHY120 students have not taken coursework assessed with an MBL framework. The majority of the EGR360 students will have taken our EGR260 (Statics) course the previous year. EGR260 is also taught with a MBL assessment framework. The MBL framework employed is centered on learning through practice and coaching – making mistakes and learning from those mistakes, frequent low-stakes assessments, analyzing the results of those assessments for further practice and coaching on that skill or for moving forward to the next skill. Assessments of all foundational skills are either Mastered or Not Yet. We know that this approach has positive effects on student learning [5], and others are examining the effects on anxiety in the students [6]. With the present study, we test the effect of the MBL approach on developing a positive Failure Mindset with the following hypotheses.

- H1 At initial assessment, third-year students will exhibit a higher propensity toward a positive Failure Mindset than the entering first-year students.
- H2 The measure of Failure Mindset will increase over the semester for all three groups of students.
- H3 The first-year students in the MBL course will exhibit a more positive Failure Mindset at the end of the semester than those not enrolled in an MBL course.

We will also examine any correlation between a Failure Mindset and course performance.

Methods

We surveyed Elizabethtown College PHY120 and EGR360 students at the start of the semester, at midterm, and at the end of the semester using a previously developed assessment [7, 8].

Elizabethtown is a small residential college with 200 engineering students.

Please rate the extent to which you agree or disagree with the following statements. For each question choose from the following alternatives: 1 – Strongly Disagree; 2 – Disagree; 3 – Neither Agree nor Disagree; 4 – Agree; 5 – Strongly Agree

1. The effects of failure are negative and should be avoided.
2. Experiencing failure facilitates my learning and growth.
3. Experiencing failure depletes my health and vitality.
4. Experiencing failure enhances my performance and productivity.
5. Experiencing failure inhibits my learning and growth.
6. Experiencing failure improves my health and vitality.
7. Experiencing failure debilitates my performance and productivity.
8. The effects of failure are positive and should be utilized.

These questions substitute failure for the word stress in the Stress Mindset Measure (SMM) previously validated as reliably indicating views on the enhancing vs. debilitating effects of stress (Cronbach's $\alpha > 0.8$) [7, 4]. The average across all eight items on the Likert scale was computed for each student with items 1, 3, 5, and 7 reverse-coded to produce a single Failure Mindset assessment measure [8].

We included all eight questions although previous studies omitted the health and vitality questions (questions 2 and 5) when applying to failure [4, 8]. We included these questions in the survey, but as detailed in the Discussion, we did not use these questions in the primary data analysis.

In the end-of-semester survey, we also asked the students the following two open-ended questions:

1. How would you define a healthy mindset toward failure?
2. How has this semester changed your Failure Mindset, positively or negatively?

The responses were thematically grouped using ChatGPT, by supplying the full set of student responses and prompting the AI to summarize the the responses. After a few passes, similar groupings were combined, and we asked the AI to identify specific quotes that reflected this theme.

Only students 18 years and older participated. All procedures were approved by our IRB, and all participants completed a Statement of Informed Consent form before taking each of the surveys.

Thirty-three to 40 students participated in each of the PHY120 surveys and 33 to 38 participated in the EGR360 surveys.

We also surveyed two additional populations at the mid-term and end of term. A parallel group of first-year students not enrolled in PHY120, but taking a Calculus course instead (non-PHY120), and a group of four second-year students participating in an off-site immersive project-based learning semester utilizing MBL assessments at the Greenway Institute.

The first two hypotheses were tested using unpaired student t-test comparisons with a significance of $p < 0.05$. The third hypothesis was tested with a linear regression $r^2 > 0.9$.

With the four students at Greenway, we used a semi-structured interview process to better understand students' views on assessment, learning, and failure.

Results

Overall, the students tended to have a mindset biased toward the positive. No statistically significant differences were measured between populations or over the semester (Figure 1). None of the three hypotheses were supported by this data. We did see slightly more positive mindsets in the four study-away students, the largest difference - between the PHY120 students and the Greenway study-away students at the end of the semester - approached significance at $p < 0.1$.

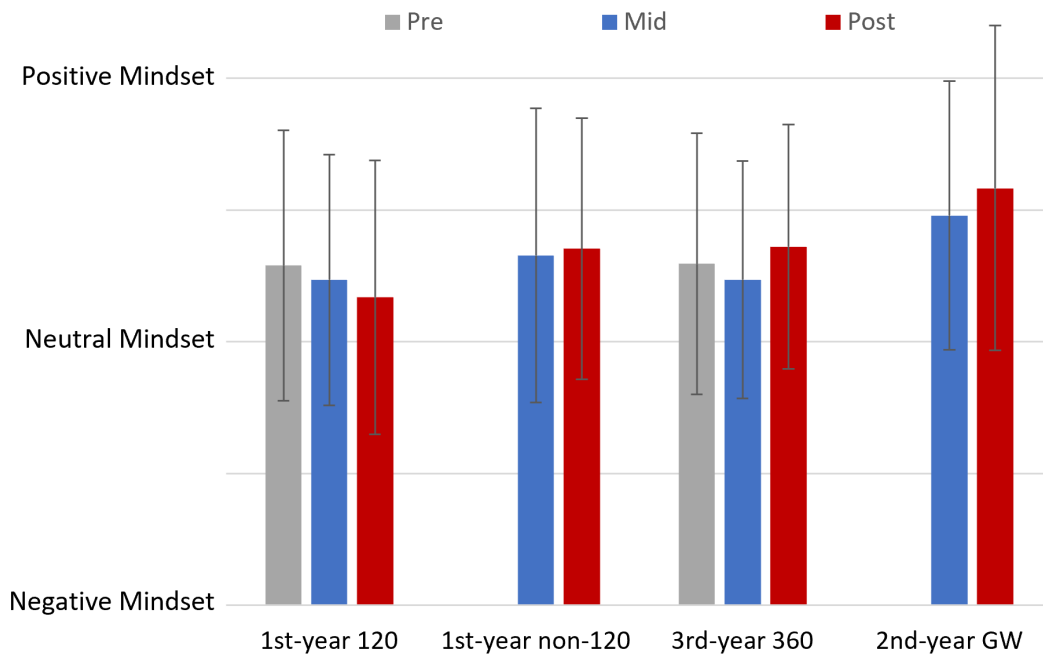


Figure 1: Composite Failure Mindset for four groups of students: first-year students in an MBL course (PHY120, n=33-40) and those not in an MBL course (non-PHY120, n=16-17), third-year students in an MBL course (EGR360, n=33-38), and second-year students in an immersive MBL-assessed project-based learning curriculum at Greenway (GW, n=4). No significant differences were found.

The end-of-semester open-ended responses provided a better window into the development of the Failure Mindset in these students. The students collectively described a positive Failure Mindset in terms of learning from failure, being willing to take risks, and demonstrating resilience by moving forward out of failures.

1. Learning and Growth:

“Seeing each failure as a stepping stone to success is important; nobody is going to get something the first time.”

“You definitely need failure to help yourself grow.”

“Failure can be used to figure out what went wrong, and learning from those mistakes facilitates learning.”

“Being able to work through problems and figure them out after trying multiple times. Need to be able to figure out what you are doing wrong and how to fix it.”

2. Reflecting and Moving Forward:

“A healthy mindset towards failure is knowing that it’s not the end of the world when you fail. There [are] always other chances to work harder and prove yourself.”

“Do not [be] afraid to fail. Being open to trying hard things without knowing the outcome.”

“It is hard to fail over and over again, but it motivates me to try and do better.”

“Seeing all failure as an opportunity to grow instead of an absolute measure of your ability to learn.”

“A healthy mindset towards failure is one that is focused not on the failure itself but on what can be improved moving forward. Using it to fuel your learning by figuring out what went wrong and improving on that.”

3. Risk-Taking, Persistence, and Resilience:

“Being motivated to do better after facing failure repeatedly, to bounce back and do better in the future.”

“A healthy mindset towards failure is recognizing that failure is possible and always a risk of attempting something new.”

“It is being able to fail but not being discouraged but rather thinking ‘I’m about to learn something.’ It’s being glad you failed, finding your hiccup(s), and then moving forward with your new knowledge.”

“Being open to trying hard things without knowing the outcome.”

Despite occasional negative moments or challenges, most students concluded that the overall impact on their mindset has been positive. Students reflected on their positive adaptations, learning that failure is OK and leveraging failure into motivation to move forward. One student identified that while the MBL course improved their mindset, others undercut that progress.

1. Positive Adaptation:

“I’m eager to bounce back and learn once I experience failure.”

“Instead of dwelling on my losses, I have learned to analyze my failure and learn how to be better next time.”

“I have started to recognize patterns in my failures and successes and how I instinctually react to them.”

“I’ve gotten more used to failure and then overcoming that failure.”

2. Motivation and Resolve:

“I think this semester has shown me that sometimes no matter how hard you work you still fail, but that shouldn’t stop you from still working hard. If anything, it should motivate you to keep moving forward.”

“This semester has taught me that it is okay to fail. It’s okay to be upset when you do bad, but it motivates you to do better.”

3. Mixed or Neutral Responses:

“I think negatively because failure is something that you are penalized so heavily for. If you fail at doing something, you might not pass the class. [PHY120] was the only class that positively impacted me with failure because you knew what you had to do [to do] better.”

“It really hasn’t changed mindset. Failure comes with growth; you can never really grow if there is not failure.”

4. Acceptance of Failure as part of the learning process:

“This semester has made me appreciate failure much more.”

“This semester and all mastery-based classes remind me how important it is to practice and fail in order to learn and progress.”

To test H3 we plotted the composite mindset score against the number of skills the students mastered in the EGR360 course. In each of these courses, the number of skills mastered directly correlates to the grade earned in the course. We found no correlation between these two measures in this group or any of the other groups (Figure 2).

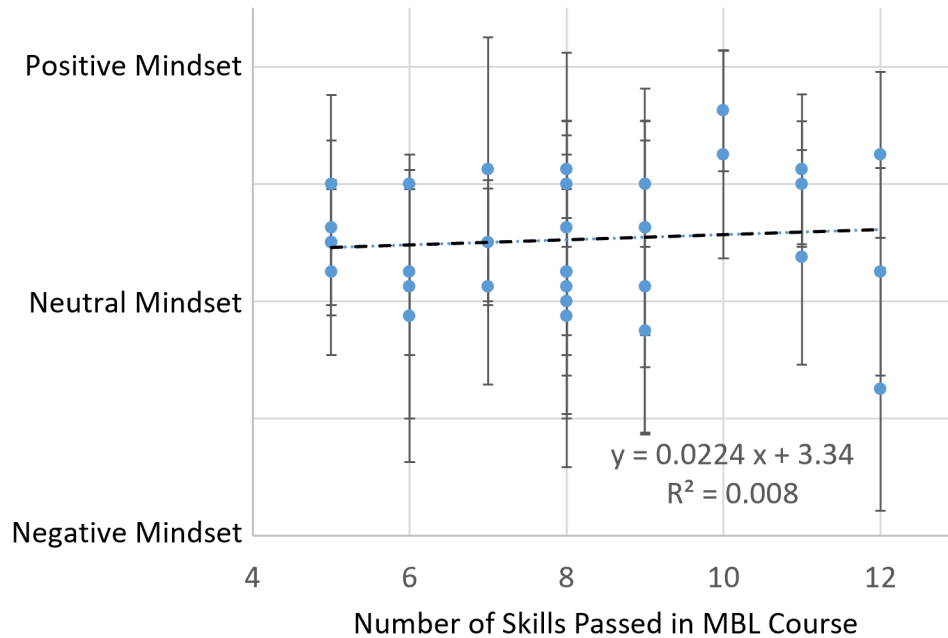


Figure 2: Composite Failure Mindset vs. the number of skills passed in this MBL assessed course.

At the Greenway off-site project-based learning campus, students were interviewed and prompted to reflect on their experiences with mastery-based assessment and attitudes toward failure as a result.

“Before starting at Greenway, my definition of failure was that I’m dumb or I can’t achieve something. But here my definition of failure is I’m not there yet. And the key word is yet. It kind of allows me to see that progress is like steps. It’s not like a dead-end road. Just because you made it halfway up the steps you still don’t see the top doesn’t mean that you should stop. And so it’s definitely changed my view to where I see failure as progress.”

“...when you are failing at these solutions, you’re actually finding new ways to solve the solution and weeding out the ways that don’t work and the ways that do work.”

“Because of the mastery-based assessment, I’m a lot more comfortable taking risks and trying new things. Because I know if it takes me a while, I can keep trying until eventually I get it. And I’m not going to be punished for taking a while to learn something. So I can try new things.”

“...failure at Greenway is really an opportunity to try again. It’s an opportunity to get better. It’s not something that’s punished. It’s not something that’s necessarily bad, it just means there’s more work to be done.”

“...Failing means that you have an opportunity to grow, and then being able to take that and continue on with it through the mastery-based learning turns a failure into a step toward success.”

“...Risk taking facilitates learning. Making mistakes facilitates learning.”

Discussion

Our preliminary results did not support any of our three hypotheses. However, we uncovered several insights into the development of a positive Failure Mindset in these students in both the quantitative and qualitative data.

This initial data set includes a small population of students with no more than 40 participating in any single measure. The study away group in particular only included four participants. These study away students tended to indicate a more positive Failure Mindset at the end of the semester (approaching significance with $p < 0.10$). However, they were likely biased toward more risk tolerance as a group of students willing to spend a semester off-campus in the first offering of a new program, and we did not survey these students at the start of the semester.

As mentioned in the methods did not include questions 3 and 6 relating to health and vitality in our dataset. We observed that students responded with a less positive mindset to these two questions than they did to all other questions ($p < 0.005$, Figure 3). These questions probed how failure made students feel rather than how they responded to failure and constantly pushed all results toward a neutral mindset. Students generally understood the value of failure in learning new things, but most still indicated that failure depleted their health and vitality. Although we did not include these questions in our data, the insight could be valuable when helping students separate the natural negative feeling of failure from how they respond.

We also observed that students consistently indicated a productive failure mindset on positively framed questions (2, 4, and 8) as opposed to the negatively framed questions (1, 5, and 7), $p < 0.01$ - Figure 3. The students were less willing to reject the negative effects of failure than they were to agree with the positive effects. This observation also provides an interesting framework for discussions of learning from and persisting through failure with our students. In particular, changing the way we frame failure alone can have a positive effect on our mindset.

Generally, students displayed a positive mindset towards failure seeing it as an opportunity for learning and growth. However, some students felt that the message from other courses was that all failure is negative. The mastery-based PHY120 course gave students multiple opportunities to pass skills which readily cultivates a mindset of “If I don’t get it this time, I can keep working and get it soon.” Other courses not using an MBL format, are structured differently with assignments and deadlines where students have one opportunity to submit work, and must do so on time to receive full credit. Repeatedly submitting work late or neglecting to submit work would be considered a developmental failure, and a type of failure that should be avoided.

We recognize the need to communicate the difference between acute and developmental failure in all courses, not just MBL courses, at the beginning of each semester. Acute failure is normal and expected part of learning where individuals make mistakes and can recover from these errors with minimal consequences. An example of acute failure would be earning a poor grade on a low-stakes assessment. Acute failure is what the Failure Mindset is seeking to embrace. In contrast, developmental failure results when students continually experience acute failures and do not respond with the appropriate action. As we continue this research, we will monitor students’ attitudes and responses to both acute and developmental failure.

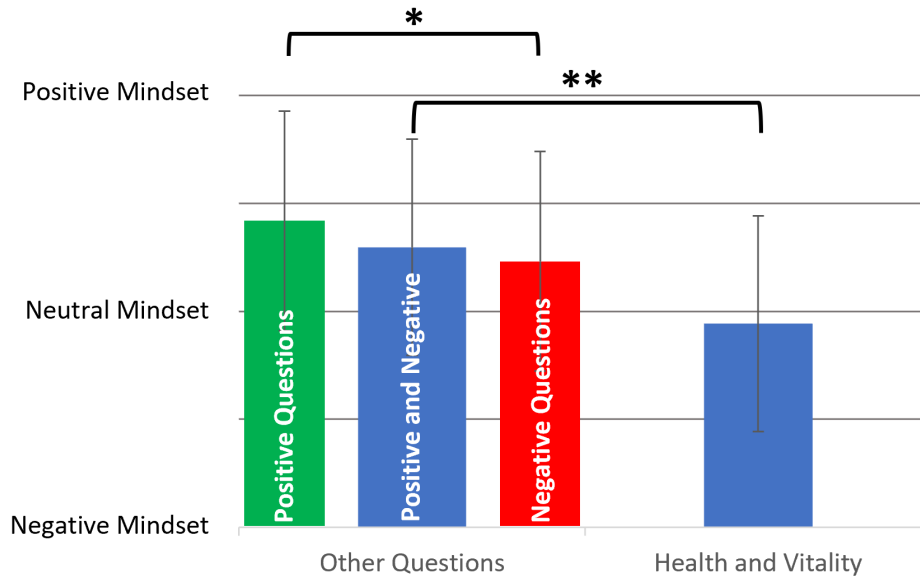


Figure 3: Comparison of Question types, *Positively framed questions compared to negatively framed questions $p < 0.01$, and ** the health and vitality questions compared to all other questions $p < 0.005$

Surprisingly, we did not see any correlation between mindset and course grade (Figure 2). However, the students not enrolled in the PHY120 course did tend to have a more positive Failure Mindset than the PHY120 students. This correlation could be confounded by overall academic success. These students placed into the college with a stronger mathematics placement and generally had a higher degree of academic success in this first semester.

Our continued work will evaluate the normalization of failure and how students respond positively or negatively to failure. We aim to establish the impact of students analyzing their failures and how they respond to those failures. We will explore expanding the Failure Mindset survey to incorporate existing surveys designed to assess risk tolerance, and survey all participants at the start and end of each semester. We plan to collect data on the first open-ended question at the start of the semester and develop a coding system to systematically score these qualitative responses.

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