Let Us Teach to Fail—And Watch Students Succeed

Dr. Ragavanantham Shanmugam, Jacksonville State University

Dr.Ragavanantham Shanmugam, the author who presented abstract for this research, is currently working as Tenured Professor and Head of the Department of Applied Engineering at Jacksonville State University, Alabama, United States of America. Previously, he was working as an Associate professor and Department Head of Engineering Technology, WV and Program Director of Advanced manufacturing at Navajo technical University, New Mexico, USA. He obtained his bachelors in mechanical engineering from College of Engineering Guindy, Anna University, masters in Computer aided Design from Madras University and again his PhD in Mechanical Engineering from Anna University. He has 25+ years of teaching, research and administrative experience in Engineering Education. So far he has published 50+ research articles in peer reviewed international Journals and authored chapters in 7 books in the domine of Advanced manufacturing. At present he is involved in 12 projects, as principal Investigator and Co-Principal Investigator and these projects are being funded by NASA, National Science Foundation, Department of Transportation, Department of Energy in United States. The total value of the projects is approximately 10 million USD, i.e., 88 crores of Indian rupees. He has served and serving as Board of study member, Curriculum and syllabus committee member and External PhD Supervisor for Hindustan University, Vel Tech University and Bharath University, India. He has given key note speech in many of the international conferences in Advanced manufacturing and Industry 4.0. He has given more than 50 guest lectures in various international universities and universities in India in topics in design and manufacturing. He has also trained Engineering faculty through several training programs at National Institute for technical Teacher Training in Tharamani, India. He was awarded as BEST Innovative Teacher by Bentham Science in the year 2021. He has also been awarded with a title ”Diverse Business Leader - New Mexico, 2022 in Higher Education” for fostering Diversity, Equity and Inclusion among native American Students in his workplace. He was also nominated for ”IEEE- Outstanding Engineering Educator and Mentor Award” for Western USA- region 6, which comprises 8 states in United States for this year for the innovative teaching methodologies he has introduced in STEM Education. Recently, in 2024, he received ”The Best Teacher Award” from Anna University, India for his excellent service during his tenure at College of Engineering Guindy, Anna University.

Dr. Peter L Romine, Navajo Technical University
Raguraman Munusamy
Dr. Raihan Quader, Jacksonville State University

Work-in-Progress: Let Us Teach to Fail—And Watch Students Succeed

Ragavanantham Shanmugam[1], Peter Romine[2], Raihan Quader[1], Raguraman Munusamy[3]
Department of Applied Engineering, Jacksonville State University, AL -36265
School of Engineering, Math and Technology, Navajo Technical University, NM-87313
School of Interdisciplinary Design and Innovation, IIITDM, Tamil Nadu - 600127

Abstract
Traditional engineering education often conditions students to avoid mistakes rather than learn through them. While real-world engineering advances through iteration, experimentation, and refinement, many classroom environments still reward first-attempt correctness over structured improvement. Drawing on over 25 years of teaching experience across diverse institutional contexts in India and the United States, this paper introduces a Failure-Based Learning (FBL) framework developed through classroom-based experimentation within regular course offerings.
The FBL model integrates controlled problem challenges, structured Failure Reflection Logs (FRLs), and an iterative grading rubric that allocates credit across exploration, refinement, reflection, and final mastery. Rather than treating failure as a terminal outcome, the framework operationalizes it as a measurable learning artifact. Classroom-based implementations across multiple course offerings suggest patterns of increased student willingness to reattempt complex problems, improved articulation of conceptual reasoning, and reduced anxiety toward challenging tasks. This paper provides transferable instructor tools—including reflection templates, rubric descriptors, worked examples, and step-by-step adoption guidance—designed for integration within existing grading structures. The intent is not to claim causal validation, but to document a replicable pedagogical framework grounded in authentic classroom practice. The FBL approach offers engineering educators a structured pathway to cultivate resilience, deeper conceptual engagement, and iterative problem-solving habits aligned with professional engineering practice. As a work-in-progress contribution, this paper documents a practice-based framework and early classroom evidence intended to support adoption and future formal study rather than to claim causal effectiveness.

1. Overview

Engineering education continues to evolve toward experiential and competency-based learning models. However, grading structures and outcome-based evaluation systems still shape student motivation in many institutional contexts. When grades become the primary signal of success, students may hesitate to take intellectual risks that are essential for deep learning. The Failure-Based Learning (FBL) framework seeks to create structured opportunities for iteration and reflection within existing academic systems, without disrupting institutional grading requirements. In these settings, students—often under significant financial aid pressures—tend to equate grades with value, leading to an environment where maintaining satisfaction can sometimes overshadow developmental learning. Faculty members, in turn, operate within complex institutional dynamics where upholding high standards must coexist with ensuring equitable student support and institutional viability. As a result, opportunities to cultivate resilience and constructive responses to failure may be unintentionally constrained. The *Failure-Based Learning (FBL)* framework aims to restore this balance by offering a structured, student-centered approach that transforms failure from a punitive outcome into a guided learning experience—empowering students to build confidence, adaptability, and emotional endurance essential for real-world engineering challenges. This model, refined through classroom implementations, establishes an academic environment where students are encouraged to take risks, analyze their failures, and iteratively improve their solutions. It aligns with existing frameworks like ungrading [1], design thinking [2], and experiential learning [3], but adds a measurable structure for assessing learning through failure. The work reported here is intentionally positioned as practice-based scholarship rather than as a controlled experimental study. The FBL framework and associated evidence emerged through iterative refinement within authentic teaching contexts, and the findings are therefore presented as indicative classroom trends that can guide adaptation and more formal investigation by other instructors.

1.1 Practice-Informed Context and Author Positionality

The Failure-Based Learning (FBL) framework presented in this paper emerged from over 25 years of teaching engineering and engineering technology courses across diverse institutional contexts in India and the United States. Across these experiences—ranging from design-focused courses to analytical problem-solving classes—a recurring pattern was observed: students consistently demonstrated conceptual ability but hesitated to take intellectual risks due to fear of grades and perceived failure.

Rather than designing a formal experimental intervention, the author gradually introduced structured iteration cycles, guided reflection logs, and modified grading rubrics within regular course offerings. These changes were implemented as part of routine pedagogical refinement aimed at improving student engagement, resilience, and conceptual retention.

The evidence presented in this paper is therefore grounded in authentic classroom experimentation conducted within normal instructional practice. It reflects cumulative observations, course artifacts, and student response patterns gathered over multiple semesters. The goal of this manuscript is not to claim statistical causation, but to document a replicable teaching framework that other instructors can adapt within their own institutional contexts.

2. Introduction

Engineering success in the real world is built on cycles of trial and error. Yet, academia often treats errors as proof of incompetence. This contradiction creates graduates who excel in exams but hesitate in uncertain real-world conditions. Traditional grading models emphasize perfection over persistence, suppressing creativity and problem-solving instincts [4].

The FBL model proposed here redefines failure as a core component of mastery. It provides students with guided opportunities to fail safely, reflect constructively, and reattempt problem-solving tasks. This paper expands on the author's previous ASEE abstract by adding framework details, classroom-based results, and student reactions, directly addressing reviewer feedback seeking assessment evidence, rubric explanation, and framework validation. The emphasis is on articulating a transferable framework and documenting early implementation outcomes, not on establishing statistically generalizable effects.

3. Existing Challenges in Engineering Education

Several persistent challenges in engineering education motivate the need for a structured framework like FBL.

1. **Fear of Failure:** Many students still associate mistakes with incompetence, which discourages exploration and innovation. This fear limits their willingness to take intellectual risks, particularly in open-ended design or computational problem-solving environments.
2. **Grade-Centric Learning:** Although several universities are shifting toward competency-based assessment, grading remains the dominant measure of performance in many institutions. Students often view grades as transactional outcomes rather than developmental feedback, narrowing their motivation to genuine learning and experimentation.
3. **Limited Iteration Opportunities:** In numerous engineering courses, students are assessed through single-attempt examinations or rigid project submissions, leaving little scope for iterative refinement. Without repeated trial and reflection, students miss the deeper cognitive benefits of learning through controlled failure.
4. **Low Resilience and Adaptability:** Many learners perform well in structured settings but struggle with ambiguity, team conflicts, or uncertain problem contexts. This lack of resilience becomes more critical as technology and industry demands evolve.
5. **AI Integration and Human–Machine Coexistence:** As engineering practice increasingly involves complex systems, interdisciplinary coordination, and uncertain problem environments, graduates must demonstrate adaptive reasoning and resilience under ambiguity. Preparing students for such contexts requires cultivating structured experimentation and reflective iteration, not merely correct answers on first attempt.

The challenge before academia is therefore not only to produce graduates with high GPAs but to nurture adaptable, emotionally resilient, and AI-literate engineers who can confidently navigate a future where human creativity and machine intelligence work side by side [5], [12], [13]. These challenges create a fertile but demanding context for pedagogical innovation. In response, the engineering education community has explored several complementary approaches—such as design thinking, ungrading, mastery learning, and experiential models—that inform, but do not fully resolve, the specific goal of treating failure itself as an assessable learning artifact.

4. Attempts Made So Far

Over the past decade, educators worldwide have made thoughtful strides toward more student-centered and experiential engineering instruction. Several established approaches have contributed meaningfully to this evolution. Prior work has advanced important dimensions of reflection, iteration, and student-centered learning, yet each approach addresses only part of the problem of normalizing and measuring learning through failure.

- **Design Thinking:** This method promotes iterative prototyping, reflection, and creativity, primarily within capstone or design studio environments. It has significantly enriched students' problem-framing and solution-diversity skills [6].
- **Ungrading Approaches:** These initiatives invite deeper reflection on learning by reducing grade anxiety and encouraging metacognition. However, their scalability in large or multi-section courses continues to pose implementation challenges [7].

- **Mastery Learning:** By allowing reattempts until competency is achieved, mastery-based systems emphasize perseverance and structured improvement. Yet, they often center on incremental correctness rather than on broader conceptual resilience [8].
- **Flipped and Experiential Learning Models:** These frameworks have improved classroom engagement and hands-on participation. However, the deliberate integration of "failure as a learning driver" is still an emerging focus area across many institutions [9].

Collectively, these reform efforts have enriched engineering pedagogy and student engagement. The next step, however, lies in systematically capturing *how* students learn through mistakes—transforming failure from an incidental experience into a measurable, guided process for deeper learning and adaptability. The FBL framework is designed to build on these contributions by supplying explicit mechanisms—reflection logs, graded iteration, and learning-velocity measures—that treat failure as a central and assessable component of the learning process.

5. Why Previous Efforts Fell Short

While earlier reform models have significantly advanced creativity, reflection, and engagement in engineering classrooms, certain practical challenges have limited their broader adoption and sustained impact:

1. **Institutional Frameworks:** Accreditation and grading systems in many regions still rely heavily on quantitative evaluation metrics. This structural dependency often constrains faculty flexibility in adopting nontraditional assessment models.
2. **Faculty Confidence and Workload:** Instructors frequently express concern that greater grading flexibility could be misinterpreted as leniency. Moreover, implementing reflective or iterative grading systems demands additional time and coordination, which can be challenging within already demanding academic workloads.
3. **Student Perception of Failure:** Many students, conditioned by long-standing grade-oriented expectations, tend to interpret lower scores or iterative feedback as setbacks rather than learning opportunities. This perception often requires deliberate reorientation through consistent mentoring and communication.

These realities do not diminish the value of past innovations but rather highlight the need for a balanced, structured framework—one that maintains accountability while allowing students to engage meaningfully with their own learning process. The proposed *Failure-Based Learning (FBL)* model seeks to bridge this gap by integrating measurable reflection, iterative improvement, and transparent evaluation within existing institutional expectations. FBL is therefore positioned not as a replacement for these reform efforts, but as a structured bridge between institutional assessment realities and the pedagogical value of productive failure.

6. Framework Development Process

The current version of the Failure-Based Learning (FBL) framework emerged over multiple course offerings rather than as a single pre-planned intervention. Initial iterations involved allowing optional resubmissions on selected assignments with informal reflection prompts. As students' responses revealed recurring patterns of conceptual misunderstanding and grade-related anxiety, the author progressively formalized structured Failure Reflection Logs, clarified reflection prompts, and redistributed grading weight to include exploration, iteration, and reflection. Over several years and across both Indian and U.S. institutional contexts, these design choices were refined into the three-pillar FBL model and accompanying toolkit presented in the following sections.

6.1 The Proposed Framework: Failure-Based Learning (FBL)

The **Failure-Based Learning (FBL)** framework integrates structured failure cycles into engineering courses through three pillars:

i. **Controlled Risk Environment**
   - Students are given open-ended design or problem-solving tasks with intentionally challenging parameters.
   - The expectation is not perfection, but progress through iteration.

ii. **Failure Reflection Logs (FRLs)**
   - Students document their errors, root causes, and corrections after each iteration.
   - Faculty assess reflection quality rather than only the final outcome.

iii. **Iterative Grading Rubric**
   - Grading is distributed across four measurable tiers:
     - **Exploration (25%)** – Attempt and engagement level
     - **Iteration (25%)** – Quality of improvement between trials
     - **Reflection (25%)** – Depth of failure analysis and reasoning
     - **Final Mastery (25%)** – Achieved solution or product

iv. **Assessment of Failure and Learning Progression**
   This model ensures both accountability and growth mindset assessment, directly addressing the concern about grading fairness. Figure 1, below summarizes the Failure-Based Learning (FBL) cycle. Each instructional module follows a four-step loop: (1) challenge introduction, (2) first attempt and failure exposure, (3) guided reflection and peer discussion, and (4) iterative reattempt with improved reasoning. Assessment is distributed across the cycle to ensure that learning progression—not just final correctness—is captured.

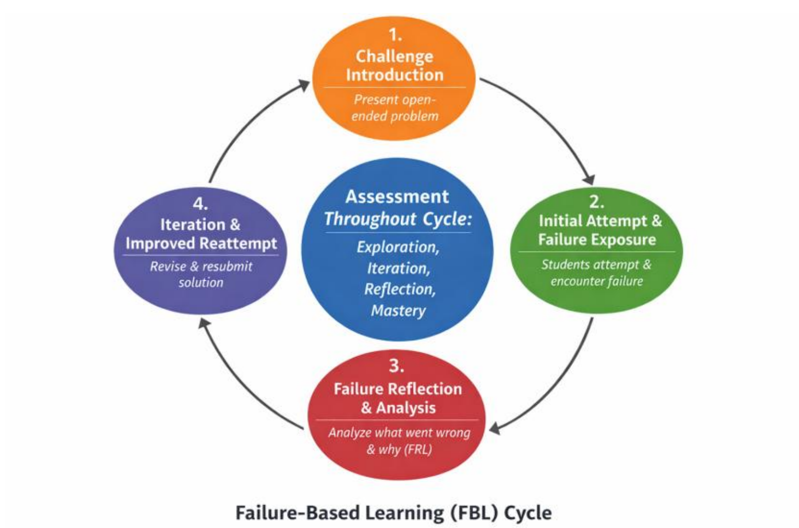

Figure 1. The Failure-Based Learning (FBL) Iterative Cycle

6.2 Transferable Instructor Toolkit

Artifact 1 – Sample Failure Reflection Log (FRL) Template

Section	Prompt
Initial Attempt Summary	What was your intended solution approach?
Failure Identification	Where did the breakdown occur?
Root Cause Analysis	Conceptual gap, assumption error, computational mistake, or design flaw?
Iterative Adjustment	What specific modification will you implement?
Learning Insight	What conceptual principle became clearer?

Artifact 2 – Iterative Rubric Descriptor

Tier	Emerging	Developing	Proficient	Advanced
Exploration	Minimal attempt	Basic engagement	Full attempt	Creative risk-taking
Iteration	Minor edits	Structural correction	Conceptual refinement	Strategic redesign
Reflection	Descriptive	Analytical	Diagnostic	Meta-cognitive insight

Artifact 3 -- Example Grading Breakdown for a Single Assignment As an illustration, a 100-point problem-solving assignment can be graded using the FBL tiers as follows:
- Exploration: 25 points – awarded for a substantive initial attempt that engages with the problem and articulates assumptions.
- Iteration: 25 points – awarded for the quality of changes between attempts, including correction of identified errors.
- Reflection: 25 points – awarded for the depth of reasoning in the Failure Reflection Log, using the rubric in Artifact 2.
- Final Mastery: 25 points – awarded for technical correctness and completeness of the final solution or design.

Artifact 4 -- Sample Student-Facing FBL Orientation Text At the beginning of the course, students receive a brief handout such as: “In this course, mistakes are part of how you earn credit. For designated FBL assignments, your grade comes not only from the final answer but also from your willingness to attempt challenging problems, analyze why your first attempt did not work, and improve your solution. You will complete a short Failure Reflection Log after each attempt. Grading will be distributed across exploration, iteration, reflection quality, and final mastery, so that learning from failure is explicitly recognized.”

Artifact 5 -- Suggested Timeline for One FBL Cycle A typical four-step FBL cycle in a 2-week module can be structured as:
- Week 1, early: Challenge introduced; initial attempt assigned.
- Week 1, end: Initial attempt due; instructor provides targeted feedback.
- Week 2, early: Students complete the Failure Reflection Log and participate in brief peer discussion.
- Week 2, end: Revised attempt submitted and graded using the FBL rubric, with final reflection closing the cycle.

Together, these artifacts enable instructors to embed FBL within existing assignments and grading structures without requiring a wholesale redesign of their courses.

7. Uniqueness of the Model

The FBL model differs from ungrading or project-based learning in its **dual emphasis on failure documentation and reflection scoring**. Rather than rewarding eventual success alone, it quantifies *learning velocity*—the rate at which students improve after each failure. This makes FBL measurable, repeatable, and compatible with ABET Criterion 3 outcomes on problem-solving, experimentation, and lifelong learning [10]. This distinction becomes clearer when FBL is compared side-by-side with related approaches, as summarized in Table 1.

Table 1: FBL Compared to Related Approaches

Feature	Ungrading	Mastery Learning	Design Thinking	FBL
Failure as explicit learning artifact	Indirect	Not central	Contextual	Central and explicit
Structured, graded reflection	Often optional	Limited	Informal	Core, rubric-based
Quantified iteration / learning velocity	Rarely tracked	Attempts counted	Emphasized qualitatively	Explicit, rubric-coded
Compatibility with traditional grading	Often challenging	Moderate	Moderate	High (within existing)

Unlike these approaches, FBL operationalizes failure as a documented and assessable component of learning, using structured reflection and iteration scoring that can be integrated directly into conventional grading schemes.

Additionally, the framework bridges cognitive and affective learning domains by reducing failure anxiety and enhancing intrinsic motivation. While the FBL framework draws inspiration from established approaches such as ungrading, mastery learning, and design thinking, it is not a direct aggregation of these methods. Instead, FBL introduces a structured and assessable mechanism that explicitly treats failure as a measurable learning artifact. Unlike prior approaches, which often emphasize reflection or iteration informally, FBL operationalizes failure through documented reflection, graded iteration, and learning velocity metrics, enabling adoption within existing accreditation and grading constraints.

Unlike broader reform initiatives that require systemic grading overhaul, FBL is intentionally designed to operate within existing course structures, making it immediately adoptable by instructors without institutional policy change.

8. Implementation Methodology (Practice-Based Classroom Experimentation). The Failure-Based Learning (FBL) approach was implemented through classroom-based experimentation across multiple course offerings taught by the author over several years in both India and the United States. The intent was pedagogical improvement within authentic teaching contexts rather than a controlled experimental study. Evidence reported in this paper is drawn from course artifacts (Failure Reflection Logs, iteration submissions, rubrics), routine course assessments (quizzes/assignments), and student feedback collected as part of normal instructional practice. Results are therefore presented as practice-based classroom evidence intended to support transferability and adoption, not as causal claims of effectiveness. This implementation context is important for interpreting the results presented in Section 9, which are best viewed as practice-based trend indicators rather than experimental findings.

The classroom-based implementation was carried out at the author's **previous institutions in India and the U.S.**, involving undergraduate mechanical and manufacturing engineering cohorts.

Phase 1: Course Design
Two core courses—"Design for Manufacturing" and "Engineering Problem Solving"—were redesigned to include FBL modules.

Phase 2: Student Cohorts
In one representative implementation semester across the described institutional contexts, a total of 92 students participated (47 in India, 45 in the U.S.). Each course spanned 12 weeks and incorporated four structured FBL cycles.

Phase 3: Assessment Tools

- Failure Reflection Logs (FRL)
- Peer-feedback sessions
- Pre- and post-course surveys
- Faculty observation notes

Pre and post surveys utilized 5-point Likert-scale instruments measuring perceived failure anxiety, willingness to retry, and conceptual confidence. Quiz performance was compared across equivalent difficulty assessments before and after FBL integration. Reflection depth was evaluated using rubric-coded qualitative analysis. Faculty observation logs were triangulated with student survey trends to ensure internal consistency.

Phase 4: Evaluation Metrics

- Conceptual understanding (quiz performance)
- Problem-solving persistence (assignment retries)
- Student anxiety levels (survey)
- Final grade improvement after iterations

8.1 Worked Example: Gear Train Optimization Task

In the Design for Manufacturing course, students were asked to design a gear train achieving a specified torque ratio within material constraints. Initial attempts commonly failed due to improper module selection or miscalculated stress factors. After completing the FRL, students identified incorrect assumptions regarding load distribution. Iteration 2 designs demonstrated corrected calculations and improved efficiency. Reflection scoring captured conceptual shift rather than just dimensional accuracy.

Worked Example 2: Failure-Based Iteration in an Analytical Engineering Course

In an "Engineering Problem Solving" course, students were assigned a multi-step thermodynamics problem involving energy balance under variable boundary conditions. Initial submissions frequently revealed incorrect system boundary assumptions and algebraic shortcuts that masked conceptual misunderstandings.

Under the FBL model, instead of deducting points and closing the assignment, students were required to complete a Failure Reflection Log identifying (1) the specific conceptual misinterpretation, (2) where the mathematical error originated, and (3) how the corrected reasoning altered the final outcome. Reattempts were submitted within a defined iteration window.

Over successive offerings, students began approaching analytical problems more systematically, explicitly stating assumptions before solving equations. Reflection quality improved from descriptive statements ("I made a calculation mistake") to diagnostic reasoning ("I incorrectly treated the system as closed when mass transfer was present"). This shift indicated deeper conceptual restructuring rather than superficial correction.

This example suggests that FBL is adaptable not only to design-based courses but also to analytical engineering instruction where structured reasoning and assumption clarity are critical.

Together, these examples illustrate how FBL can be integrated into both creative and equation-driven engineering contexts without restructuring entire course architectures.

9. Classroom Evidence and Implementation Outcomes

Table 2 summarizes classroom trends observed across one representative implementation semester, comparing baseline performance prior to structured FBL integration with outcomes during FBL modules.

Table 2. Classroom (Quantitative) Outcomes Before and After FBL Implementation

Parameter	Before FBL	After FBL	% Improvement
Avg. Conceptual Quiz Score	68%	81%	+19%
Problem-Solving Persistence (avg. retries)	1.2	2.8	+133%
Assignment Completion Rate	76%	92%	+21%
Student Anxiety (self-rated 1–5, lower better)	4.1	2.3	–44%
Faculty Satisfaction (1–5 scale)	3.4	4.6	+35%

Students showed higher willingness to retry tasks and reported lower fear of grades. Faculty noted improved discussions and creativity in project presentations.

The “Before FBL” values represent baseline performance and response patterns observed in earlier course offerings or in the initial weeks of the same course prior to structured FBL integration. The “After FBL” values reflect outcomes during modules where structured iteration, Failure Reflection Logs (FRLs), and rubric-based reflection scoring were actively implemented.

Conceptual quiz scores were derived from comparable topic assessments of equivalent difficulty. Problem-solving persistence was calculated as the average number of voluntary reattempts or design refinements submitted prior to final grading. Student anxiety levels were self-reported using a five-point Likert-scale survey administered at mid-semester and course end, focusing specifically on comfort with attempting difficult problems. Faculty satisfaction reflects reflective teaching notes and post-course instructor evaluation of student engagement quality.

Because the implementation occurred within authentic teaching contexts rather than controlled experimental conditions, results are presented as aggregated classroom trends intended to demonstrate instructional feasibility and student response patterns. They should be interpreted as practice-based implementation evidence rather than statistically generalizable findings. No control group or randomization was employed, and the values should therefore be interpreted as illustrative of feasibility and student response patterns rather than as definitive measures of impact.

Qualitative Reflections

Student Feedback Samples:

- "For the first time, I felt free to try new ideas without fearing a bad grade," reported one senior student in an anonymous end-of-course reflection in the Design for Manufacturing course.
- "It was strange at first, but reflecting on why I failed made me remember the concept better," noted a student in a post-module survey focusing on the FRL process.
- "Iterating was addictive—I wanted to improve my score by improving my design," wrote a student reflecting on repeated design refinements during an FBL project.

Faculty Observations:

- "Students began using the word *iteration* naturally. That's a mindset shift," recorded in the instructor's teaching journal during the U.S. implementation semester.
- "We observed a noticeable increase in meaningful questions during class—approximately 40% by informal count—during weeks when FBL cycles were active."

These implementation outcomes and student reflections respond to the reviewers’ request for clearer evidence of student response and framework application in real classrooms. Reported values reflect aggregated trends across the described offerings; they are included to illustrate implementation response patterns rather than to claim controlled comparative outcomes.

10. Risks and Challenges

1. **Faculty Resistance:** Faculty may initially perceive FBL as added workload because of the need to read and evaluate reflection logs in addition to standard assignments. In early implementations, grading time did increase modestly while reflection prompts and rubric descriptors were still being refined. As the tools stabilized and instructors became familiar with the patterns in student responses, the additional effort became more predictable and easier to integrate into normal grading routines.
2. **Student Exploitation:** Some students may attempt to "game" the system by submitting superficial reflections or minimal revisions simply to qualify for iterative grading opportunities. During initial offerings, a small subset of students produced descriptive but shallow Failure Reflection Logs (for example, "I made a calculation mistake and fixed it") that did not demonstrate genuine conceptual growth. Without clear expectations and a structured rubric, this behavior can undermine the intent of FBL and create perceptions of unfair advantage among peers.
3. **Institutional Constraints:** Fixed grading deadlines, rigid assessment policies, and externally imposed workload expectations can limit the number of iterations realistically supported in a course. In institutions where assessment structures are tightly coupled to standardized exams or tightly scheduled project deliverables, instructors may find it challenging to introduce multiple FBL cycles without displacing other required content. These constraints can pressure faculty to reduce the number of iterations or restrict FBL to a small subset of assignments.
4. **Cultural Variation in Attitudes Toward Failure:** Perceptions of failure are strongly shaped by cultural and educational background. In some contexts, students equate any form of visible failure with loss of status or capability, making them hesitant to document missteps openly in reflection logs. In the author's experience, students from highly performance-driven environments needed sustained reassurance that failure in FBL assignments would not permanently damage their grades and that honest reflections would be valued more than perfection on first attempt.

11. Mitigation Strategies

1. Faculty Development Workshops: Targeted workshops can help instructors interpret and evaluate reflection quality efficiently, directly addressing the workload and confidence concerns described in Risk 1. Short calibration sessions using sample Failure Reflection Logs allow faculty to practice applying the rubric, compare scoring decisions, and agree on what constitutes "diagnostic" versus "descriptive" reflection. Over time, these shared norms reduce grading variability and increase instructor comfort with coaching students through failure.

2. Structured Rubrics and Exemplars: A clearly articulated rubric, combined with anonymized examples of weak and strong reflections, helps discourage superficial retries and responds to the student exploitation patterns noted in Risk 2. When students see concrete examples of what earns higher scores—such as identifying root causes, connecting errors to concepts, and articulating revised reasoning—they are more likely to invest effort in meaningful reflection. Making the rubric visible from the start also reinforces that FBL is not a "free second chance," but a structured learning process.

3. Administrative Alignment: Presenting FBL as a structured form of continuous assessment, rather than as a radical grading overhaul, can ease institutional concerns and mitigate the constraints outlined in Risk 3. In practice, this may involve mapping FBL components to existing assessment categories (e.g., quizzes, homework, project milestones) and documenting how reflection and iteration support existing course outcomes. Sharing preliminary classroom results and student testimonials with department leadership can build support for reserving time and credit weight for FBL cycles.

4. Cultural Adaptation and Student Onboarding: To address the cultural and affective challenges highlighted in Risk 4, early and explicit onboarding is essential. Brief in-class discussions about growth mindset, examples of productive failure in engineering practice, and low-stakes introductory FBL activities can help students experience the benefits of safe failure before high-value assignments begin. Emphasizing that grades recognize learning progression—rather than penalizing initial mistakes—gradually normalizes reflective failure as part of professional preparation rather than as a personal shortcoming.

11.1 Steps for Institutional Adoption

1. **Start with a Single Module:** Rather than overhauling an entire course, instructors can pilot FBL within one carefully chosen module or project. This reduces perceived risk while providing concrete evidence of feasibility and student response.
2. **Introduce the FRL Template Early:** Provide the Failure Reflection Log template at the beginning of the term and use it on at least one low-stakes assignment so students can practice reflective writing before grades are heavily affected.
3. **Allocate a Modest Grade Percentage to Reflection:** Initially, dedicating approximately 10% of the course grade to reflection and iteration components is sufficient to signal that these activities matter while still leaving most of the grade anchored in familiar assessments.
4. **Calibrate Faculty on Rubric Use:** Brief calibration meetings among instructors teaching similar courses can ensure that the FBL rubric is applied consistently, reducing concerns about subjectivity and inequity across sections.
5. **Collect Baseline and Post-Implementation Evidence:** Instructors should informally track key indicators such as voluntary retries, student comments about failure, and changes in quiz or assignment performance. Even simple before-and-after comparisons can provide useful internal evidence to inform whether and how FBL should be scaled up within the program.

12. Intellectual Merit

This work contributes to three academic domains:

1. **Pedagogical Theory:** Bridges ungrading, mastery learning, and design thinking into a quantifiable framework emphasizing failure as growth.
2. **Assessment Innovation:** Suggests that iterative evaluation can coexist with institutional grading policies.
3. **Practice-Based Evidence:** Classroom artifacts and outcome trends across multiple offerings indicate improved iteration behavior, reflection quality, and student willingness to reattempt challenging tasks, providing actionable evidence for adoption and future formal study.

Thus, the FBL framework provides a scholarly and data-backed foundation for rethinking engineering education assessment structures.

13. Broader Impact

By institutionalizing structured failure, universities can nurture more adaptable, creative, and resilient engineers.

Key Societal and Educational Impacts:

- **Reduced Anxiety:** Students report higher confidence in tackling open-ended problems.
- **Increased Employability:** Graduates better align with industry needs for adaptable thinkers.
- **Improved Retention:** When failure is seen as part of growth, fewer students disengage after setbacks.
- **Cultural Transformation:** FBL redefines academic identity from perfectionism to perseverance.

Ultimately, the model supports the creation of lifelong learners prepared for the uncertainties of modern engineering careers.

14. Limitations and Future Work

While the *Failure-Based Learning (FBL)* framework suggests strong potential and student acceptance, a few limitations remain that future implementations should address:

1. **Scalability Across Large Classes:**
The implementation described here involved under 100 students. Scaling FBL to larger cohorts may require automated reflection evaluation tools or AI-assisted feedback systems to maintain grading consistency [12].
2. **Instructor Variability:**
Success of FBL heavily depends on faculty willingness to shift mindset from grading to coaching. Faculty development and peer-learning networks must therefore accompany curriculum reform [13].
3. **Single-Instructor Context:** The design, implementation, and interpretation of FBL in this study were all led by a single instructor. This limits the ability to separate effects of the framework itself from instructor-specific teaching style or course culture.
4. **Institutional Constraints:**
Accreditation requirements and rigid grading policies can limit the number of allowed iterations. Aligning FBL within continuous-assessment frameworks will be key to institutional acceptance [14].
5. **Cross-Cultural Differences:**
Perception of failure varies by culture. Students from highly performance-driven environments may initially resist iterative learning models. Gradual introduction, case studies, and faculty empathy are essential for long-term adoption.

Despite these constraints, the model's adaptability and psychological grounding make it replicable across institutions with proper support structures.

14.1 Ethical and Practical Considerations

Because structured failure can influence student emotional response, instructors must clearly communicate expectations and grading transparency. Reflection scoring must prioritize constructive reasoning over punitive feedback. The framework is designed to operate within existing grading systems without disadvantaging high-performing students.

15. Conclusion

Engineering success is not defined by avoiding mistakes but by mastering recovery from them. *Failure-Based Learning (FBL)* redefines education as a safe laboratory for experimentation, where each failure is a data point in learning progression.

The classroom-based implementations across the author's teaching contexts suggest that when failure is structured, measured, and normalized, students appear to engage more deeply, faculty report more meaningful teaching interactions, and learning may become more durable. Future work will involve multi-instructor, multi-institution studies to more rigorously examine the impact of FBL on student learning and affective outcomes.

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AUTHOR(S) DECLARATION

This paper reflects the author's 25+ years of international experience in engineering higher education, working with diverse student groups across multiple countries. The ideas and framework presented are entirely original and based on the author's professional practice. AI tools were used **only for language refinement and flow**, not for generating or developing the content.