Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #47830

# Applying an Alternative Grading Methodology to an Advanced Engineering Mathematics Course

**Dr. Neil Rogers, U.S. Air Force Academy**

Lt Col Neil Rogers, PhD is Senior Military Faculty and an Assistant Professor of Electrical and Computer Engineering at the United States Air Force Academy. He is the department's research director and oversees a number of courses in electromagnetics, communications, and applied field theory.

**Dr. Kaitlin Fair, United States Air Force Academy**

**Applying an Alternative Grading Methodology to an Advanced Engineering Mathematics Course.**


# Abstract

Traditional percentage-based grading in lecture-based courses often fails to provide meaningful insights into a student's true understanding of the course material. Instead, it encourages students to focus on earning partial credit rather than mastering concepts and more importantly, retaining key information for future courses and professional applications. In this work, we assess the effectiveness of an alternative grading scheme in an advanced undergraduate mathematics course for Electrical and Computer Engineering (ECE) applications, aimed at improving student understanding of core concepts. These concepts are crucial for success in follow-on ECE courses, where instructors frequently report that students, despite having performed well on previous exams, demonstrate little to no retention of relevant concepts. In our implementation of this alternative grading model, often referred to as mastery-based or standards-based grading, students are given clear, granular learning objectives (LOs). Students' understanding of these objectives is explicitly assessed throughout the semester. Rather than receiving partial credit, students earn full points for fully correct answers or zero points for incorrect answers. Students are then provided with constructive feedback that guides them toward improving their understanding of the learning objective, without revealing the correct answer. Students are then allowed to revise their work on the assessment to improve their score. To evaluate the effectiveness of shifting to alternative grading, we discuss our observations and experiences as instructors, survey students about their experiences with the new grading approach, and propose adjustments for future implementations along with a detailed plan for quantitative analysis.


# 1 Motivation

In many courses and institutions, students prioritize achieving a certain GPA over exercising intellectual curiosity or truly engaging with the course material on a deeper level. This pressure is often fueled by the need to meet scholarship requirements, maintain academic standing, or satisfy future employers or graduate schools that emphasize GPAs as a key metric. Alternative grading systems aim to acknowledge these constraints while incentivizing intellectual curiosity, allowing students to engage deeply with the material without sacrificing the practical importance of their academic records.

Alternative grading also gives more meaning to earned grades over traditional grading models by

ensuring they directly reflect a student's demonstrated understanding of key concepts. Instead of relying on partial credit or averaging scores across graded events, this approach requires students to meet clearly defined learning objectives before receiving credit. Furthermore, assessments are clearly and transparently mapped to learning objectives. As a result, grades become a more accurate representation of what students understand at the end of a course.

In this work, we describe the implementation of an alternative grading scheme in an advanced undergraduate mathematics course for Electrical and Computer Engineering (ECE) applications, aiming to enhance student understanding and retention of core concepts. We discuss our observations and experiences as instructors, survey students about their experiences with the new grading approach, suggest adjustments for future implementations, and propose a detailed plan for future quantitative analysis to assess its long-term impact.

## 2 Alternative Grading Landscape

Alternative grading is gaining momentum in adoption throughout higher education[1,2,3], but the term "alternative grading" is generic and is often applied in a number of contexts. Here, we describe some of the many approaches that fall under a similar umbrella; these "early" adopters have explored concepts such as alternative grading, mastery-based grading, specification-based grading, and ungrading – all with reported success in promoting engagement, mastery, and eventual student success.

- **Alternative Grading (AG):** Alternative grading approaches aim to shift away from traditional letter grades and percentage scores to systems that promote learning, student agency, and equitable assessment practices. Key motivations include:
  - Focus on Learning: Emphasis on skill acquisition and deep understanding rather than high-stakes exams or rote memorization.
  - Reducing Stress: Elimination of the competitive grading curve and de-emphasis on grades as the sole measure of success.
  - Flexibility and Equity: Creating fairer systems that accommodate diverse learning paces and styles.[4]
  - Emphasis on the process of making mistakes, receiving feedback, revision, and eventual mastery.
- **Mastery-Based Grading (MBG):** Mastery-based grading focuses on whether students have achieved specific learning outcomes or skills, emphasizing progress over time. Its characteristics include:
  - Clear Learning Objectives: Learning is broken into discrete objectives students must demonstrate mastery of before progressing.
  - Iterative Feedback: Students receive targeted feedback and multiple opportunities to improve their work.

  - De-emphasis on Deadlines: Focus on achieving mastery regardless of when it occurs within the course timeline.
  - This approach has shown promise in STEM fields, where technical skills are central, but it requires careful design to avoid overloading instructors with assessments.

- **Specification-Based Grading (SBG):** evaluates student work against predefined criteria, with an emphasis on binary or tiered assessment: a task either meets specifications or it does not. Features include:
  - Detailed Rubrics: Students are provided with explicit success criteria for assignments.
  - Pass/Fail Basis: Grades are often binary for individual tasks, though students can achieve higher grades by completing more tasks or exceeding baseline expectations.
  - Encourages Consistency: Work must consistently meet rigorous standards, promoting attention to detail.
  - Studies suggest SBG helps clarify expectations and supports student accountability, though it can be challenging to implement without clear communication and buy-in from both students and faculty[5].

- **Ungrading:** an alternative approach to assessment that de-emphasizes traditional grades in favor of more meaningful feedback and self-reflection. The goal is to shift the focus from earning points or letters to genuine learning and mastery[6]. Key principles of ungrading include:
  - Student Autonomy: students often assess their own work, sometimes in collaboration with instructors, fostering self-awareness and responsibility for their learning.
  - Feedback over Grades: Instead of assigning a grade, instructors provide qualitative feedback to help students understand strengths and areas for improvement.
  - Growth and Iteration: Encourages revision and improvement by viewing learning as a process rather than a one-time event.
  - Intrinsic Motivation: By removing the pressure of grades, students may feel more free to explore, take risks, and engage deeply with the material.
  - End-of-Term Assessment: In many ungrading models, students propose their final grade based on evidence of their learning, often with guidance from the instructor.

Despite the varied implementations and philosophies of non-traditional grading approaches, the approaches share a number of common themes, which informed our pilot:

- Feedback: meaningful feedback is key to learning and growth. Alternative grading practices acknowledge that assigning partial credit is a weak feedback mechanism – one that students often ignore and one that does not force them to engage meaningfully with the process of learning. Furthermore, instructors become focused on fairness and determining "the right" amount of partial credit, which may or may not accurately reflect their actual understanding. Alternative grading seeks to elevate the quality and importance of instructor feedback in the learning process.

- Clear objectives & meaningful assessment: traditional grading can obscure the relationship between assessments (usually exams), a student's grade, and the learning objectives. AG techniques seek to clearly identify the relationship between these.
- De-emphasizing points earned: in a traditional grading scheme, students will fight for every point, often arguing or hoping for a curve. In many cases, the students' overall grade may not indicate their understanding of the learning objectives; but is rather determined by their collection of the "right number" of points. AG methods seek to refocus student energy on correcting mistakes by removing penalties for revision and relaxing deadlines.
- Emphasizing Intellectual curiosity & intrinsic motivation: by removing the stress of grade obsession and time compression, students are free to determine their own fate by the effort they expend in mastering concepts. In this way, we stimulate creative, critical thinking and produce graduates who are more ready to enter the modern workplace and make an immediate impact.
- Normalizing the revision process: in traditional grading, mistakes are considered unacceptable and primary indicators of student capability. However, this approach creates self-perception issues within students – if they didn't get it right the first time, they'll never get it right. In an AG approach, mistakes are encouraged as a primary teaching/learning mechanism. When coupled with feedback and the ability to revise work, students are much more likely to fully engage in the learning process and thereby succeed[7].

Finally, non-traditional grading approaches are not without their challenges. For example:

- Student Adaptation: Transitioning from traditional systems can confuse students accustomed to percentage-based grading. Therefore, clear guidance and early buy-in are critical.
- Instructor Workload: Alternative grading systems often require substantial upfront effort in designing rubrics, setting learning outcomes, and providing high-quality feedback.
- Equity and Access: These approaches can reduce inequities by valuing progress and learning, though barriers may still arise if students lack access to resources (including time and confidence).

Overall, these grading systems share the goal of fostering a deeper, more meaningful educational experience, with ongoing research and case studies contributing to best practices for their implementation. It is also noteworthy that this is not a one-size-fits-all approach, and faculty at specific institutions are subject to unique constraints on a case-by-case basis. Our institution enforces some unique constraints that are discussed as applicable. Furthermore, neither of the authors had any expertise in alternative grading and we consider this initial attempt a pilot upon which we will build future efforts based on our experiences and student feedback.

# 3 Implementation

For the Advanced Engineering Mathematics ECE Applications course, we implemented an alternative grading system designed to provide more meaningful grades while improving student learning

and retention. Neither instructor had any previous experience or training in alternative grading approaches; therefore, this paper captures our initial implementation, which we have since refined. Approximately 40 junior-level students were enrolled in the course over two sections (one taught by each of the authors). Due to other course constraints, the control group for any quantitative analysis would be offerings prior to the conversion to alternative grading.

Our methodology curated concepts from each of the approaches described in the previous section; it focused on mastery-based grading, maximizing engagement, and providing assessments specifically aligned with the course's granular learning objectives. This section provides an overview of the key elements that define our grading strategy for this course. Here, for context, we should at least mention some of the unique constraints of USAFA. First, all students must receive a letter grade for each course. Secondly, a final exam constitutes at least 25% of the total course grade. Finally, 50% of student work within each course must be individual effort. These constraints are non-trivial and required modification of our initial approach – we identify and address these considerations in the relevant forthcoming sections.

## Learning Objectives

Learning objectives (LOs) formed the foundation of the course's assessment strategy. Each learning objective represented a critical concept required for success in advanced Electrical and Computer Engineering (ECE) coursework. For this particular course, it was important for us to construct LOs with a high level of granularity. This may not prove as important for higher level courses, where LOs can be tightly coupled and are by nature, less distinct. Below are a few examples of LOs from this course:

**Chapter 1 - Discrete Mathematics**

1.1 I can compute the minimum-cost path (i.e. solve the traveling salesman problem) using brute force graph theory methods.

1.2 I can perform manual modulus calculations with positive and negative integers.

**Chapter 2 - Probability**

2.1 I can calculate the probability of an event occurring given prior knowledge of conditions related to the event using Bayes' Theorem.

2.2 I can apply Bernoulli trials to determine the probability of an outcome given independent events.

We evaluated students' mastery of these objectives through carefully designed assessments, which mapped directly to individual learning objectives. Each chapter culminated in an assessment, on 2-3 week intervals, and students would generally have one week to complete their first attempt. Assessments covered multiple learning objectives, so we covered each LO at least once. Problems emphasized a real-world engineering application of the LOs and assessment problems were graded

on a binary scale (1 for complete correctness, 0 for incorrect). Students who did not achieve mastery (i.e., scored 0) received meaningful feedback and were allowed to revise and resubmit their work once within one week of grades being published. Revision consisted of not only correcting errors, but articulating their initial mistakes and discussing lessons learned. In some cases, students completely missed deadlines or failed to show effort on assessments. These students earned their revision opportunity by researching an ECE application of the learning objective and giving a short presentation. This approach reinforced both accountability and applied learning, while adhering to the overall philosophy of our approach.

We graded assessments at the objective level, with each question weighted equally and aligned to a single learning objective. For instance, the course included 49 learning objectives, resulting in a total of 49 assessment questions, spread across 8 assessments throughout the semester. We then calculated a student's final learning objective score as the proportion of objectives mastered. For example, if a student earned a score of 1 for 42 objectives and 0 for the remaining 7, their final learning objective score for the course was $\frac{42}{49} = 85.7\%$. This explicitly informs the students that they mastered 85.7% of the concepts covered in the course. These assessment questions were a critical component of the grading structure, as they constituted 40% of the final course grade.

## Engagement

Student engagement can be difficult to measure objectively, but is a key component of the learning process. Therefore, we designed the grading system to encourage active participation in the course. Engagement credits could be earned by answering questions related to 13 assigned videos, attending extra instruction sessions outside of class, and completing ungraded practice problems meant to prepare students for assessments and examinations.

Although we capped engagement credits at 18 for grading purposes, students who earned additional credits beyond this threshold received bonus percentage points on their final course grade, and the opportunity to skip a single problem on the final exam. This provided an incentive for continued active participation. The engagement score contributed 10% to the final grade, ensuring students consistently interacted with the material, instructors, and peers.

## Midterm and Final Examinations

The course incorporated a midterm and final exam as cumulative assessments. These exams implemented a specifications-based scoring system with a straightforward scoring rubric; since we offered no retakes. Each problem in the midterm and final was worth 1 point and followed three key specifications: selecting the correct mathematical framework, accurately applying the given data, and ensuring solutions were neat and easy to grade. Students earned 1 point for a problem if all specifications were completed with at most trivial math errors, indicating a clear understanding of the concept. A student earned 0.5 points on a problem if they selected the correct mathematical framework but did not apply the given data correctly, indicating partial understanding of the concept. A student earned 0 points on a problem if they did not select the correct mathematical framework, their solution was not neat, or no work was shown, indicating a lack of understanding.

At USAFA, at least half of a student's final grade must be based on individual effort. This course therefore included both a midterm and a final examination. The midterm served as a preview of the final exam structure, allowing students to familiarize themselves with the format and expectations. The midterm covered learning objectives addressed up to that point in the semester, while the final was cumulative, covering all objectives from the entire course. This structure emphasized the retention of concepts and ensured a comprehensive assessment of individual understanding. Both exams were weighted equally, each contributing 25% to the final grade.

### Grading Platform

To cope with the logistics of increased assignment submissions due to retakes, we used the Gradescope[8] platform for assignment submissions and grading. Gradescope provides an efficient mechanism for revision, along with a straightforward way to compare revised and original work. Furthermore, Gradescope allows users to track grades and subsequent revisions with minimal effort[9].

## 4 Findings

### Instructor Experience

As instructors, we observed a marked improvement in the quality of student questions during office hour sessions and classroom discussions. We clearly observed that students were prioritizing a deep understanding of the concepts over simply arriving at correct answers, or amassing a certain number of points and passing on partial credit. Additionally, students were actively reviewing and utilizing the detailed feedback provided on assessments. This is something students openly admit they rarely do after receiving their grades for partial-credit assignments. This change reflects a significant cultural shift toward learning-oriented behaviors, which aligns with the goals of the alternative grading framework.

Instead of spending hours adjusting grades to fit an arbitrary normal distribution, we objectively assessed student mastery of learning objectives (LOs) and focused our energy on providing meaningful instruction and feedback. Another key advantage was the removal of subjective grading decisions. With a simple 1 or 0 system, grading became entirely objective—students either demonstrated mastery or they didn't. In previous semesters, grading often involved determining who was 'less wrong' and assigning partial credit accordingly, introducing an unavoidable element of bias. This new approach eliminated that ambiguity, ensuring consistency and fairness in assessment.

We also found that in clearly defining what we wanted students to know by the end of the course, we engaged in a more critical evaluation of how we allocated time with students, ensuring that instruction was focused on only the most essential and impactful topics. If widely adopted, it would also create a transparent framework across the department, making it easier to track where key topics are taught and ensuring prerequisite knowledge is consistently reinforced. This alignment could improve curriculum coherence, helping both students and instructors better understand how courses build upon one another.

## Qualitative Student Feedback

Our implementation of the alternative grading system revealed valuable insights into its impact on student learning, instructor workload, and the adaptability required to tailor such systems to specific course needs. Regular requests for informal student feedback throughout the semester as well as formal feedback gathered during the final exam highlighted both the strengths of this approach and the challenges in shifting perceptions from traditional grading methods.

A significant number of students expressed that the opportunity for retakes made the grading system feel fair and less daunting. Retakes allowed students to focus on understanding concepts rather than resorting to 'brain-dumping' for timed examinations. Many appreciated the clarity of expectations with granular learning objectives and felt retakes alleviated the fear of making mistakes by providing a clear pathway for improvement. When asked an open-ended question about what most helped their learning in the course, the overwhelming response was 'retakes on assessments.'

Several students expressed their preference for traditional partial-credit based grading. We maintain that partial credit introduces bias and undermines the fairness and consistency of grading. As a hybrid approach, some students expressed a preference for the specifications-based rubric scoring used in the midterm and final for all assignments. However, as instructors, we note that this preference does not prioritize the feedback loop integral to the alternative grading system and may not account for how their grades might have suffered under such a scheme, where compounded errors across problems could drastically impact final grades.

Additionally, some students suggested additional tiers of scoring on the midterm and final (beyond 1, 0.5, and 0) to reflect varying levels of understanding. This feedback highlights the ongoing challenge of balancing fairness, granularity, and simplicity in assessment scoring, especially when institutional constraints require more traditional exams.

# 5 Path Forward

## Future Alternative Grading Implementation

To support future implementations, it is useful to document best practices and lessons learned to guide new instructors adopting alternative grading. Additionally, we recommend instructors that have implemented alternative grading to mentor newer faculty in making *incremental* changes toward this approach. Not only will newer faculty benefit from past experiences, but making incremental changes will allow time to refine their system, improve student reception, and ensure a smoother transition across multiple semesters.

The following recommendations stem from challenges we encountered during our initial implementation. Based on informal student feedback throughout the semester, we made several adjustments throughout the semester to assessments and the means by which students accumulate engagement points. Early assessments occasionally combined multiple objectives into a single problem or assessed a single objective across multiple problems, which created grading complexities and student frustration with understanding the total points possible. We therefore adjusted the

structure so each problem corresponded to a single learning objective. This change streamlined the grading process and better aligned with student preferences and is how we are currently employing alternative grading in other courses. We also adjusted the cap on engagement points mid-semester, as we used fewer external resources than initially planned. Until we clarified this cap clarified, students expressed discomfort with the uncertainty surrounding the total number of points. These growing pains, while expected in a first-time implementation, underscore the importance of transparency and consistency in future iterations.

Qualitative student feedback revealed that despite our best efforts, some students failed to fully comprehend the purpose and implementation of our alternative grading approach, citing confusion regarding multiple aspects of the course structure. To address this, we propose providing clearer instructions on submitting retakes in the course syllabus and during the course introduction. Furthermore, it may be possible to introduce a low-stakes skills review quiz early in the semester, exposing them to the methodology. This quiz can serve as practice for the assessment process, allowing students to engage with the retake mechanism and grading rubric (0 or 1) in a stress-free setting. We implemented this in another course with a different cohort of students and have observed far less confusion over the new grading paradigm.

We also propose streamlining the number of learning objectives (LOs) to encourage more focused engagement without sacrificing the depth of learning. With 49 LOs in our course, the sheer volume posed challenges, limiting students' ability to deeply reflect on individual concepts within a 40-lecture semester and contributing to heavy student *and* instructor workloads. Furthermore, if the entire department adopts alternative grading, articulating and aligning objectives across all ECE courses could help reduce redundancies, making it easier to streamline concepts across the curriculum. For advanced courses that emphasize critical thinking, we suggest adapting learning objectives to focus on broader, overarching goals rather than narrowly defined outcomes.

Finally, we propose that the process for submitting revised work be streamlined to improve efficiency. Initially, we followed Gradescope's recommended method[9] by creating a separate assignment for revised submissions. We instead suggest allowing students to upload a link to their revised file via a regrade request for only the problems they got wrong as a solution. This would ensure we don't regrade the entire assignment if they only missed one problem and also eliminate the need to manually consolidate grades via an external spreadsheet, which is prone to human error. Not only will this simplify the process and reduce administrative burden, it will also ease the integration of Gradescope with our Learning Management System (LMS). By tying one question to each learning objective (LO) as earlier discussed in conjunction with applying the regrade mechanism, the total points possible across all assessments would now align with the number of LOs, providing a clear and streamlined grading structure in the LMS. We implemented this approach in a separate course this semester and integration has been far simpler. This approach works best if each LO is assessed only once. Therefore, if an instructor chooses to assess the same LO multiple times, they could either increase the total points possible on assessments or revert to a more complex system, like using a spreadsheet, although as previously noted, this introduces additional administrative burden and potential for user error.

## Proposed Quantitative Analysis

To assess the effectiveness of alternative grading, we propose conducting a comparative analysis using a core course that is taught over multiple semesters. Our introductory ECE course for ECE majors is an ideal candidate, as it is a foundational course taught early in the program. This provides an opportunity to gather valuable feedback from students who have experienced traditional grading at our institution and later compare it with the outcomes of those taught under the alternative grading model.

The analysis will involve consolidating grades from several semesters for both traditional and alternative grading methods. Key data points will include trends in grade distribution and performance on specific learning objectives (LOs). By comparing these metrics, we can assess whether the alternative grading approach significantly impacted student performance and inflated or deflated grades.

In addition to grades, we will collect feedback from students about their preparedness for later ECE courses after completing this core course under both grading methods. Specifically, we will use a quick feedback form to evaluate whether students felt they retained critical concepts and skills more effectively under the alternative grading model compared to the traditional system.

We will also seek input from instructors teaching subsequent courses that rely on the core course for prerequisite knowledge. By gathering insights on how well students applied the concepts learned in the core course, we can assess how well the material was retained and utilized after being taught under each grading system. This will provide valuable data on whether the shift to alternative grading supports long-term retention and enhances students' preparedness for more advanced coursework.

This comprehensive analysis will enable us to make data-driven recommendations for future course designs and grading strategies, ensuring continuous improvement in teaching effectiveness and student outcomes.

# 6 Summary and Conclusion

This paper describes the motivation for, implementation of, and lessons learned of our first attempt at implementing alternative grading. It identifies a number of lessons learned and logistical hurdles, while making recommendations for those who wish to implement the approach. It proposes a framework for quantitative analysis, which may be conducted after several semesters in order to draw statistically meaningful conclusions. In summary, we find alternative grading to be a more effective pedagogical approach than traditional grading, and we find it rewards and motivates students to truly learn, rather than simply to achieve a grade.

## Disclaimer

The views expressed in this article, book, or presentation are those of the author and do not necessarily reflect the official policy or position of the United States Air Force Academy, the Air Force,

# References


[1] B Curley and J Downey. Implementation of alternative grading methods in a mathematical sciences course. *Journal of College Teaching & Learning*, 21:150–165, 2024. URL https://www.tandfonline.com/doi/full/10.1080/26939169.2023.2249956.

[2] Barrera A Talley J Javazon E Diaz M Anzovino ME Katzman SD, Hurst-Kennedy J. The effect of specifications grading on students' learning and motivation in a hybrid course. *International Journal of STEM Education*, 11: 10–25, 2024. URL https://pmc.ncbi.nlm.nih.gov/articles/PMC8561837/.

[3] Center for Grading Reform. URL https://www.centerforgradingreform.org/resources/.

[4] Sharona Krinsky. Grading: The (mis) use of mathematics in measuring student learning and its disproportionate impact on equity and inclusion. 2024.

[5] Caleb A Moster and Sarah Kathryn Zingales. Use of specifications-based grading in an online, asynchronous graduate organic chemistry course. In *Frontiers in Education*, volume 9, page 1379216. Frontiers Media SA, 2024.

[6] Jesse Stommel. Ungrading: An introduction. *Pedagogy*, 24(3):327–340, 2024.

[7] Tim Gorichanaz. "it made me feel like it was okay to be wrong": Student experiences with ungrading. *Active Learning in Higher Education*, 25(1):67–80, 2024.

[8] Sara A. Atwood and Arjun Singh. Improved pedagogy enabled by assessment using gradescope. In *2018 ASEE Annual Conference & Exposition*, number 10.18260/1-2–30627, Salt Lake City, Utah, June 2018. ASEE Conferences. https://peer.asee.org/30627.

[9] Gradescope. URL https://guides.gradescope.com/hc/en-us/articles/21591719559181-How-can-my-students-submit-a-revised-assignment-after-grading-is-complete.