WIP: An Alternative Grading Scheme in a Graduate Disciplinary Engineering Course

Susan Gentry
Department of Materials Science and Engineering
University of California, Davis
Davis, CA, USA
spgentry@ucdavis.edu

***Abstract*—This work-in-progress innovative practice paper describes the implementation and initial evaluation of a graduate course that has been redesigned to integrate principles of mastery and specifications grading. The target course was a graduate Advanced Thermodynamics of Solids course, a required course for students in the Materials Science and Engineering graduate program. Previously, the course used a traditional grading scheme, where students' grades were assigned based on weighted performance on homework, exams, and other projects. In 2022, the instructor redesigned the course to base students' grades on their achievement of minimum grading thresholds for each assessment category. Using virtual tokens, students could repeat assignments (including homework and midterm exam problems). Interviews with five students were conducted and initial feedback was that the unweighted grading scheme did not motivate them, although several students appreciated the ability to retake exam questions. This paper also discusses instructor reflections and insight into future work.**

Keywords—graduate education, grading systems, mastery learning, specifications grading

I. Introduction

Educators should utilize equitable grading schemes that represent students' mastery of course content. Many engineering educators have grading schemes that weight homework, tests, and other assignments to compute a final course grade; in some courses, the distribution of letter grades may be set to a normalized bell curve. In 1971, Benjamin Bloom pointed out that normalized (curved) grading schemes are not motivational and may lead to inconsistent letter grades between years. Bloom goes so far as to suggest that "we teach as though only a minority of our students are able to learn" [1]. As defined by Joe Feldman, equitable grading is accurate (complete and excludes irrelevant information), bias-resistant (promotes the success of all students, not just those who "know" the system), and motivational (promotes a growth mindset and helps students persevere) [2]. Feldman demonstrates inequitable grading through an example showing that two students' scores may vary widely depending on how an instructor weights in-class participation versus tests and projects. Furthermore, Linda Nilson points out that grades have become a "game, the objective of which is to maximize the number of points toward one's grade with the lowest possible investment of time and effort" [3]. These authors challenge instructors to consider whether their grading schemes are representative of course mastery or other factors.

Alternative grading schemes can link students' course grades to their content mastery. Mastery grading broadly describes grading methods in which grades are assigned using rubrics that define mastery of student learning objectives [1]. These grading criteria and rubrics are specified from the start of the academic term, allowing students to judge their performance throughout the course. Specifications grading is an alternative grading scheme that aligns course grades with students' mastery of course content, as described in Nilson's book *Specifications Grading* [3]. Students must meet a minimum level of mastery to receive credit on coursework, otherwise no credit is given. Grading rubrics are provided in advance so that students can assess their level of mastery in advance. These grading schemes generally give students opportunities to revise and resubmit their work to meet the requirements, often through a limited number of "tokens" provided by the instructor or earned by the student.

There is significant literature on using specifications and mastery grading schemes in undergraduate courses. For instance, specifications grading has been utilized in a broad range of undergraduate courses, including a large-enrollment organic chemistry lab [4, 5], engineering senior design [6], lower-division statics [6], and first-year engineering [6] courses. Perez and Verdin conducted a systematic literature review of mastery grading in engineering education [7]. They found that most mastery grading was applied to midterm exams and occasionally homework, and students preferred the mastery grading approaches. A separate study by Perez and Verdin also interviewed a student who described how mastery grading approaches promoted his confidence in course topics and promoted a growth mindset [8]. Schlemer and Vanasupa reported that mastery learning was integrated into 11 engineering courses at their institution and found that it reduced student stress in the classes in which it was used [9].

However, the literature lacks documented examples and research on specifications grading or mastery learning in graduate courses, particularly core science and engineering courses that are mathematically rigorous. Some universities and degree programs offer classes on a pass/fail basis or equivalent. For instance, many medical schools in the United States have switched to pass/fail grading, and studies have shown that this promoted student well-being with no significant effect on student learning [10]. However, there are few documented attempts to apply mastery grading in letter-graded graduate classes. Patrick Walden documents how they applied specifications grading in a graduate course on communication

disorders, but this was not a mathematically based course [11]. Pedagogically based teaching is important to ensure student learning, but graduate courses are often overlooked.

II. Implementation

A graduate Advanced Thermodynamics of Solids course was redesigned in 2022 to utilize mastery and specifications grading principles. The course enrolled 17 and 27 students in the Fall 2022 and 2023 academic quarters, respectively. The course is offered in a hybrid format, enrolling traditional in-person students and Distance-Learning Program (DLP) students. DLP students often work full-time at national labs, so they watch course recordings asynchronously. All students complete the same assignments on the same deadlines. This course is one of six required core courses for all students in the Materials Science and Engineering graduate program, but the only course to utilize an alternative grading scheme.

Previously, the course used a traditional grading scheme, where students were assigned grades based on weighted performance on homework, exams, and other projects such as presentations. A challenge of this grading scheme was that students assumed that poor class performance would be "curved up" rather than using absolute standards. Additionally, the instructor noted that the graduate students relied on the "hope and pray" approach to learning, in which students hoped they could solve the problems on the exams rather than developing systematic methods for solving these problems and learning from their errors.

The new grading scheme created fixed expectations, articulating the requirements for course letter grades based on minimum scores required for homework, exams, group presentations, and other instruction. In 2022, the "other instruction" category consisted of graded peer instruction activities, in which students presented the solutions to homework problems to their peers in class. An oral quiz was implemented in place of peer instruction in 2023. Both years, students were required to give a group presentation critiquing a paper. Groups were assessed on meeting published expectations for the paper summary and critique components of the presentation. The exams were designed to reinforce homework topics and were at an equivalent difficulty level. The exam questions were intended as proxies for the number of concepts that the students mastered. Letter grades were assigned based on students meeting all the thresholds in a given category. For instance, a student could earn a B+ grade by earning at least 80% on the homework, completing a group presentation summarizing a paper, earning at least 3 of 5 points on an oral quiz, and averaging at least 70% on the combined score of the midterm and final exam. The grading schemes for 2022 and 2023 are presented in Tables I and II, respectively. The grading scheme was designed to better mimic the "mastery" expectations of graduate students throughout their careers.

A key feature of mastery and specifications grading is allowing students to repeat or retake assignments, motivating them to improve, particularly if they do poorly on early assignments. In this course, students received two "tokens" and could earn a third by completing an additional assignment. Students used their tokens towards late submissions, replacing homework problems, or retaking exam questions. The most common use of the tokens was retaking midterm exam questions (up to two questions were allowed); final exam retakes were not

TABLE I. 2022 Alternative Grading Scheme

Assessment Category		**Letter Grade**							
		D	***C***	***C+***	***B-***	***B***	***B+***	***A-***	***A***
Group Presentation (Meets minimum requirements)	Summary					X	X	X	X
	Critique							X	X
Exam Problems (%)		50	52.5	57.5	62.5	67.5	72.5	77.5	82.5
Homework (%)		50	60	70	80	80	85	85	90
Peer Instruction Activities (out of 5 possible)	Participant	2	3	3	4	4	4	4	4
	Presenter	0	1	2	2	3	3	4	4

TABLE II. 2023 Alternative Grading Scheme

Assessment Category		**Letter Grade**							
		D	***C***	***C+***	***B-***	***B***	***B+***	***A-***	***A***
Group Presentation (Meets minimum requirements)	Summary					X	X	X	X
	Critique							X	X
Exam Problems (%)		50	55	60	65	70	75	80	85
Homework (%)		50	65	70	75	80	80	85	85
Oral Quiz (5 point maximum)		2	3	3	4	4	4	4	4

feasible with the academic calendar. The exam retake questions were taken from topics similar to the original question (e.g., common tangent construction of phase diagrams) but did not necessarily have the same solving steps. For example, questions about phase stability and free energy might entail sketching a plot of the free energy of two phases, whereas the retake might require students to sketch the phase stability between these two phases; both required knowledge of the thermodynamics of phase equilibrium and were from the same unit of the course. The retakes were given at scheduled times outside of class and were proctored by the instructor. The tokens allowed students to grow and learn from errors in the course.

III. Methods

This project investigates the perceptions of the graduate students who completed the Advanced Thermodynamics of Solids course at the University of California, Davis, as described above. The instructor is evaluating three hypotheses regarding graduate students' experiences of the alternative grading schemes:

- H1: Using a mastery grading scheme motivates students to focus on learning course concepts rather than earning points on assessments,
- H2: Allowing students to repeat assignments or earn credit in an alternate manner motivates students to master more course concepts rather than giving up on those topics, and
- H3: Students' preference toward repeating assignments is focused on the opportunity to boost their grades rather than subject mastery.

Structured interviews were conducted with students enrolled in these courses. Interviewees were asked about typical assignments and grading schemes they experienced in their prior courses, and reflected on their experiences and preferences. They also described their initial perceptions of the grading scheme and how those perceptions changed over the term. Participants reflected on their learning in traditional and alternative grading scheme courses. Finally, participants shared their idea of the "perfect grading scheme" they might use to motivate students. Participants were recruited from the course rosters and provided with a $25 gift card as compensation. Participants were also asked to report the following demographics: gender identity, location of undergraduate degree (United States or international), and participation in the DLP program. Due to small course sizes, demographic information was not linked to specific participants, nor was race or ethnicity collected. To limit instructor influence, an undergraduate student outside the department was responsible for scheduling, performing, transcribing, and anonymizing the interviews. Quotes from some participants are included in this paper, with pseudonyms selected by the participants. The campus Institutional Review Board (IRB) determined that the project was exempt. This paper reports on the first five of eleven interviews that were completed. These interviews were completed in April and May 2024, about 4-5 or 16-17 months after the course had concluded (depending on enrollment year).

IV. Preliminary Results

From the initial interviews, it appears that the students were ambivalent or did not like the course's non-weighted grading scheme. TN reported that they preferred traditional weighted schemes because "that's the best, the easiest for students to understand. They don't have to focus on the grading scheme.… When you have like convoluted grading schemes, it kinda makes them focus more on the grading scheme than the assignments to do." Additionally, the interviews revealed that at least one student had misconceptions about the grading scheme. Meremy recalled, "the grading was based on just the final exam and not on assignments that we did. Not on the midterm we did…. It was just that all these other things were a major of calculation to make sure that you are doing enough in the course." This statement was incorrect, as, at a minimum, the exam category combined both the midterm and final exam scores. However, it shows the student's feelings about the relative worth of homework assignments versus exam scores. These responses contradict the first hypothesis which predicted improved motivation from specifications grading.

All students were favorable about repeating assignments, particularly exam questions. TN noted that this helped when they might "not study the correct material or you could just be having an off day." Daniel also stated that they "felt less stressed about the initial attempt of the exam… [and this would] help me study the material better." Two students also noted that repeating exam problems helped them learn topics on which they initially had errors. TFC said the exam retakes "gave me more confidence on the subject matter" (Meremy), and TFC suggests that the retake "solidifies that knowledge instead of you saying, oh, I got a bad score but I'm still passing it and continuing forward. I think it's better because it, you know, gives you a reason to look at it again. Actually understand it fundamentally." Student comments show that the retake assignments improved their motivation to master initially missed information, supporting the second hypothesis. However, there is insufficient evidence regarding the third hypothesis: that the preference was based on grades, not content mastery.

V. Discussion and Instructor Reflections

The instructor designed the course grading scheme to utilize published pedagogical methods to improve student learning. The goal was to iterate towards a fully implemented specifications grading framework over time, such as basing a course grade on the number of concepts mastered. However, it is unclear whether the grading scheme enhanced student motivation. For instance, several grade categories (e.g., homework, presentation) were areas in which students traditionally did well and used to increase their final grades. Thus, the grading scheme effectively put a more significant weight on the final exam than on other aspects of the course. The letter grade cutoffs in Tables 1 and 2 were based on a historical review of past exam grades for the course, but students may not have appreciated the historical justifications. Instead, graduate students were likely accustomed to homework and presentations increasing their grades in a weighted scheme, so they may have been dissatisfied when this was no longer true. For the instructor,

it was unclear whether the alternative grading method improved student learning based on exam performance.

Allowing students to repeat assignments is a cornerstone of specifications and mastery grading so that students can learn from their errors. However, this required significant work to create and track retake assignments, even with the small class size. For instance, students were allowed to repeat up to two of the six questions on the midterm exam. The instructor wrote four new exam questions for the retake assignment each year since different students retook different problems. Similarly, new retake homework problems were created for five to ten problems each year. A similar increased workload was noted in literature by Schlemer and Vanasupa [9], highlighting that care must be taken to scale these methods to larger enrollment courses.

VI. Conclusions

The grading scheme of the graduate Advanced Thermodynamics of Solids course was redesigned using the principles of mastery and specifications grading. The aim was to motivate students to focus on topic mastery rather than course grades. However, initial interviews describe that the course grading, as described above, did not have the intended conclusion. Students were not favorable of the grading scheme as implemented in the course. They appreciated the opportunities for retaking assignments, particularly exam questions, but several students found the non-weighted grades confusing. Future work will focus on analyzing all eleven interviews and identifying changes to the course for Fall 2024.

Educators must be willing to reflect on their teaching methods using student feedback from their courses. It can be humbling to admit that a pedagogical technique did not work in a specific class or implementation. While it is unclear whether this alternative grading method improved student motivation and performance, more work remains to devise and articulate grading methods for all students. As one of the students said:

"*There's some courses where none of your homework is graded. And your whole grade is definitive only from the midterm and the final. Or maybe some courses, homework is 50% of the grade, and you know the rest of it are exams. And other courses, they have papers or group presentations, and those are also distributed differently. So. I think the surprising factor is how you could again essentially be doing the same. You're going to be performing the same in the same class, but depending on the quarter you take it or the professor that's teaching it, you could get two vastly different grades." [TFC]*

Instructors need to create transparent grading schemes in which both the students and instructor see the connections between content mastery and course letter grades, to motivate hard work and perseverance in the course.

Acknowledgment

This work was funded by the Small Grant program at the University of California, Davis. Interviews were conducted and transcribed by Akshaya Ravi.

References

[1] B. S. Bloom, "Mastery Learning," in Mastery learning: theory and practice, J. H. Block, Ed. New York, NY: Holt, Rinehart and Winston, Inc., 1971, pp. 47-63.

[2] J. Feldman, Grading for equity: what it is, why it matters, and how it can transform schools and classrooms. Thousand Oaks, California: Corwin, a SAGE Company, 2019.

[3] L. B. Nilson and C. J. Stanny, Specifications grading: restoring rigor, motivating students, and saving faculty time, 1st ed. Sterling, Virginia: Stylus, 2015.

[4] W. J. Howitz, K. J. McKnelly, and R. D. Link, "Developing and implementing a specifications grading system in an organic chemistry laboratory course," J. Chem. Educ., vol. 98, no. 2, pp. 385-394, 2021.

[5] K. J. McKnelly, W. J. Howitz, T. A. Thane, and R. D. Link, "Specifications grading at scale: improved letter grades and grading-related interactions in a course with over 1,000 Students," J. Chem. Educ., vol. 100, no. 9, pp. 3179-3193, 2023.

[6] T. M. Fernandez, K. M. Martin, R. T. Mangum, and C. L. Bell-Huff, "Whose grade is it anyway?: transitioning engineering courses to an evidence-based specifications grading system," in 2020 ASEE Virtual Annual Conference Content Access, 2020.

[7] C. L. Perez and D. Verdin, "Mastery learning in undergraduate engineering courses: a systematic review," in ASEE Annual Conference, Minneapolis, MN, 2022.

[8] C. Perez and D. Verdin, "The effect of a mastery learning course on Rafael's mindset," in 2023 Frontiers in Education Conference (FIE), 2023.

[9] L. T. Schlemer and L. Vanasupa, "Grading for enhanced motivation and learning," in ASEE Annual Conference & Exposition, New Orleans, LA, 2016.

[10] R. A. Bloodgood, J. G. Short, J. M. Jackson, and J. R. Martindale, "A change to pass/fail grading in the first two years at one medical school results in improved psychological well-being," Acad. Med., vol. 84, no. 5, pp. 655-662, 2009.

[11] P. R. Walden, "Student motivation, anxiety and pass/fail grading: a SoTL project," Teach. Learn. Commun. Sci. Disord., vol. 6, no. 1, 2022.