Adopting Alternative Grading in an Upper-Level Laboratory Course in Bioengineering

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***Abstract*—Alternative grading schemes are growing in popularity in higher education STEM courses. These schemes focus more on learning and feedback than the traditional points-based grading scheme common in the U.S., which often relies mathematical formulas to determine grades without attention to students' actual mastery of material. In the 2021-22 academic year an alternative grading scheme was implemented in an upper level required laboratory course in bioengineering at a large public university. The process of identifying and implementing the alternative grading scheme was documented and feedback was collected from students and laboratory staff during the first two semesters of implementation.**

Keywords—grading systems, laboratory, undergraduate

I. Introduction

The goal of alternative grading is to apply assessment methods that separate feedback from the final grade of the course. In the United States, traditional grading is frequently based on a weighted average of points earned throughout the course to arrive at a formulaic final grade that is indifferent to the actual learning attained by each student. Most alternative grading systems do not assign grades based on these traditional percentage or points-based scales. One alternative system is specifications grading or specs grading, where assignments are evaluated based on a predefined set of specifications that are provided to the students with the assignment. For each assignment, students earn a passing grade if they meet all of the specifications or a failing grade if they do not. The goal of specifications grading is to decrease the focus on partial credit and increase the focus on feedback and the learning process. To support the learning process, students are also able to revise and resubmit assignments to earn a passing grade.

The goals of specifications grading align with the general goals of learning from mistakes and feedback in laboratory courses. Additionally, laboratory work in industry and research does not earn partial credit for completion, it is revised until it meets a specification. Therefore, during the 2021-2022 academic year, specifications grading was applied in an advanced undergraduate laboratory course at a large research university in the Midwest. Each of the assignments had a set of specifications that were provided to the students as a rubric in the course learning management system (LMS). Each post-lab assignment could be revised once to earn a passing grade.

The specifications for each assignment and the calculation of the final grade used in this course were based on previous implementations in similar courses in the literature and through networking with other. All sections of the course in both semesters used the specifications grading system and feedback was sought from the students and laboratory staff. Changes were implemented between semesters based on this feedback.

This paper describes the details of the grading system as it was applied in the course, feedback collected, and reflections from the course instructor. The specifications grading system was successfully implemented in the fall 2021 semester, however, there were several challenges. Therefore, some improvements were implemented for the second semester and are being evaluated. The challenges and associated improvements along with other considerations for instructors considering this or similar grading systems are also included.

II. Background

There are many different schemes of alternative grading including ungrading [1], specifications grading [2], mastery grading [3], standards-based grading [4], contract grading [5], and mastery-based testing [6]. While the specific approach to calculating a final grade is different for each of these, one thing they all have in common is the reduced use of traditional points or percentage-based formulas for calculating final grades. Not all of these schemes are appropriate for STEM courses in general or lab courses in particular. After an initial review, standards-based grading and mastery-based grading seemed very similar and had multiple successful examples in STEM courses. Also, specifications grading and contract grading had some similarities but specifications grading had more resources and examples for STEM courses. For this project, mastery-based grading, standards-based grading, and specifications grading were identified as the most feasible for this course.

Standards-based grading and mastery-based grading seem to be used interchangeably in many contexts and a significant difference could not be consistently identified between the two schemes [7]. Both measure the student's achievement of skills or objectives in the course [3], [4], [8]–[13]. In these examples, students are given multiple opportunities to demonstrate their achievement or mastery of a skill. There are examples of standards-based grading in mathematics courses [3], [14]–[17], engineering courses [4], [12], [13], [18], [19], design courses [8], science course [20], and lab courses [10], [21].

Specifications grading evaluates if a student's work meets certain specifications. This would be similar to evaluating an engineering design or software application against specifications or criteria provided by the customer or manager.

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In both scenarios, the evaluation is pass or fail. The student's work or the design meets the specification or it does not [2]. If the assignment or the design does not meet the specifications, there is an opportunity for revision and reevaluation in both scenarios. There are also examples of specifications grading in math courses [22], engineering courses [23]–[25], design courses [26], science courses [27], [28], and lab courses [24].

III. Methods

Changing the entire grading scheme for a course was a multi-step process. I started by evaluating various alternative grading schemes and identifying which ones had been used successfully in laboratory or experiential learning-based courses. Ideas for alternative grading were identified in the literature as well as through networking with colleagues. Once a grading scheme was identified several changes were made to the course. First, the syllabus and other introductory materials were updated, then new rubrics were created for each assignment. Next, the course staff was trained to use the new grading scheme. Finally, the new scheme was implemented in the fall 2021 semester, updated based on feedback, and implemented again in the spring 2022.

A. Course Context

The course is a two-credit hour, semester-long, undergraduate laboratory in biomedical instrumentation. There is a corresponding lecture course that is three credit hours, and it was taught by a different instructor. The grading scheme was only modified in the laboratory course. Both courses are required for all bioengineering undergraduate students, and it is also taken as a technical elective in majors from across the College of Engineering. The total enrollment in the laboratory course was 33 students in the fall and 67 students in the spring. Each week students meet for a one-hour common introduction lecture on Mondays. Then they complete the experiment during a scheduled three-hour lab section later in the week.

There are four major assignment categories: pre-lab assignments, post-lab assignments, exams, and a design experiment. Through approximately half of the semester the students complete experiments designed by the faculty. These experiments teach the basics of amplifier circuits, filters, and eventually assembling an ECG. Then, the students build upon the knowledge they learned in these experiments to design, prototype, and test another instrument to capture a biosignal. The exams include a general safety quiz in the first week and an individual lab practical exam in the last week.

Each of the laboratory sections has a graduate teaching assistant who is assigned to teach the laboratory course. In this semester, all of the graduate TAs were in their first semester at the university. Some of them had related experience to the course content but not with the specific course. Additionally, each laboratory also has an undergraduate assistant to help with questions from students. All of the undergraduate assistants have completed the course within the last two semesters.

B. Data Collection

As part of the normal course structure, feedback was collected via an anonymous survey after the first four lab experiments were completed. Additionally, end-of-semester feedback was gathered through campus course evaluation forms.

All of the course staff meets weekly to discuss the course and prepare for the next lab. Each week we discussed grading, potential improvements, and any feedback received from students. Changes that were suggested and could be made within the semester were adopted. Additional changes were noted for future semesters.

IV. Results and Discussion

A. Identify an Alternative Grading Scheme

As discussed, there are many forms of alternative grading that have been implemented in both secondary and higher education. After reviewing all of them, eventually, two options surfaced as likely candidates for a lab course: specifications grading and standards grading. Each of these options was explored closely within the context of the course.

Standards-based grading schemes are generally based on how many times a student has demonstrated a particular skill or learning objective at a satisfactory level. To evaluate if standards-based grading would be appropriate for this course, I broke down each course learning objective into smaller measurable tasks. Then, I mapped these tasks to each assignment in the course. After I had determined that each task could be demonstrated at least twice during the semester, I evaluated the mastery grading feature in Canvas. This feature is key to implementing specifications grading at scale as it helps to track the number of times a student has demonstrated each task and at what level. After having a system in place to track task achievement, I determined an outline of how the task achievement would map into a final grade. At this point, specifications grading started to fall apart as a possible scheme for this course. Some of the tasks had multiple opportunities to demonstrate and others would only have three times to demonstrate a task and that would only happen if they were strategic about the instrument selected for the project. So, for students who struggle in the first labs, it would be difficult to successfully demonstrate a task at least twice (a common practice in specifications grading) without careful planning. On the other hand, students who were successful early in the semester and carefully tracked task achievement would not necessarily need to complete lab 7 to pass the course. Since these scenarios did not seem equitable for all students, I decided to consider another scheme.

Specifications-based grading schemes are based on a student meeting stated specifications for an assignment. Assignment evaluation is usually pass/fail. The specifications likely differ by assignment and are clearly stated before the assignment is submitted. Like standards-based grading, specifications-based grading schemes also allow multiple tries on an assignment or room to fail some assignments and still earn a passing grade. Additionally, each assignment already had a rubric that could be used as a starting point for a specification-based rubric. The next step was to evaluate tools in Canvas and determine how the final grade would be calculated. The rubric and complete/incomplete assignment grading in Canvas were sufficient to implement specifications grading at scale. The final grade calculation was determined based on implementations in other courses; more details are provided in the next section. Ultimately specifications grading was selected because of its successful use

in similar courses, alignment with the evaluation of work products in the industry, and the simplicity of tracking progress.

B. Adopting the Grading Scheme

The trickiest part of an alternative grading scheme is to determine how calculate into a final letter grade for the course. Since this was a change only to a single course, the final grade still had to fit within grade options expected by the university. As there are few example approaches to this in literature, additional approaches were solicited from other instructors who currently implement alternative grading practices.

For this course, the final grade was split into two parts: base grade and modifier. The base grade determined how the student earned an A, B, C, D, or F. Then the modifier determined if the base grade would be modified by a plus, a minus, stayed the same, or lowered the base grade to the next letter. The assignments were split into two categories: one submission and multiple submissions. The assignments that only had one submission contributed to the modifier part of the grade and the assignments that could be revised contributed to the base grade. One of the key attributes of alternative grading is the ability to demonstrate a skill or objective more than once to earn a passing grade. Therefore, I wanted the most important part of the grade to be based on items that the students had the chance to revise.

The base grade included the safety quiz (three automatically graded attempts via the LMS), each post-lab assignment, and the design experiment (three versions of varying difficulty). The base grade was calculated as follows:

- For a base grade of A:
  - Earn at least 95% on the safety quiz, and
  - Earn a pass on all eight post-lab reports, and
  - Earn a pass on the advanced design experiment.
- For a base grade of B:
  - Earn at least 90% on the safety quiz, and
  - Earn a pass on seven post-lab reports, and
  - Earn a pass on the standard design experiment.
- For a base grade of C:
  - Earn at least 80% on the safety quiz, and
  - Earn a pass on six post-lab reports, and
  - Earn a pass on the basic design experiment.
- For a base grade of D:
  - Earn at least 70% on the safety quiz, and
  - Earn a pass on five post-lab reports, and
  - Complete the basic design experiment.
- For a base grade of F:
  - Do not meet the criteria in any of the above grades, or
  - Commit academic dishonesty as defined below in the Academic Integrity policy.

The modifier to the grade included the pre-lab assignments (eight total), the lab practical exam, and unexcused absences from laboratory sections. The modifier was calculated based on these assignments as follows:

- Add a plus (+) to the base grade if the student earns
  - A pass on 6 or more pre-lab assignments, and
  - At least 85% on the lab practical exam
- Add a minus (-) to the base grade if the student earns
  - A pass on 2 or 3 pre-lab assignments, or
  - Between a 50% and 69% on the lab practical exam, or
  - An unexcused absence from your lab section
- Lower the base grade one full letter if the student earns
  - A pass on less than 3 pre-lab assignments, or
  - Less than 50% on the lab practical exam, or
  - Two or more unexcused absences from lab

This final grade calculation worked for the fall 2021 semester, however, some adjustments were made for the spring 2022 semester which will be discussed later. Several students were initially confused by their grades, believing that failing a pre-lab had more impact on their final grades. Therefore, about halfway through the semester, a spreadsheet was provided to the students to track their grades for the rest of the semester. Since a running total for a grade was not possible in Canvas with this scheme, this spreadsheet is an acceptable alternative for students who like to track their progress throughout the semester.

C. Implementation in a Laboratory Course

Once the grading scheme and final grade calculation were confirmed, the next step was to change the rest of the course materials and train the course staff. All assignments were turned in electronically in the Canvas. Each assignment was set to complete/incomplete grades for the grade book in Canvas. Each assignment also had a rubric with two columns: pass and incomplete/missing. In each assignment, instructions stated that the student had to earn a passing grade on each row of the rubric to earn a passing grade on the assignment. The rubric was the implementation of the specification for each assignment. The most difficult part of creating the rubrics was clearly identifying the line between pass and fail. For some specifications, like formatting, it was clear that the student either followed the formatting instructions or they did not. For other specifications, like designing a filter or laying out a breadboard in TinkerCAD in a pre-lab assignment, it is not as clear what are acceptable mistakes for a passing grade and what are mistakes that are not acceptable. It was even more difficult to communicate these differences to students and to maintain consistency in grading. As the semester progressed, the lab staff started a collaborative document to track mistakes that were acceptable for a pass and which mistakes were not. This document helped improve consistency between the graders and clarified expectations.

Once the course-level logistics were determined, training the graders to use the new scheme was the next step. In both semesters, we started with an overview meeting that discussed the philosophy of grading and feedback in a laboratory course. Then the teaching assistants were given the same three post-lab assignments to grade and then we discussed the grades and feedback as a team before they were asked to grade post-lab assignments for their sections. Post-lab assignments were split by section so that each teaching assistant could adapt feedback based on what they observed during their laboratory session. This training was a good start for the teaching assistants but could still be improved.

There were also a few unexpected logistics issues in both semesters. First, the complete/incomplete setting in Canvas automatically sets an assignment to complete if they earned any number of points, not if they earned all of the points. It was a manual process for the graders to mark the assignment as incomplete if the student did not earn a pass on all rows of the

rubric. Additionally, the location of the feedback made a difference in Canvas. We found that using the annotation tool made the feedback clearer for the students, as many students missed feedback in the comments section of the rubric. The comments section of the rubric was also problematic because the rubric is not specific to the version of the assignment. To keep the gradebook neat, the student would turn in the revised assignment to the same assignment drop box as the first version. This made it easy for the grader to switch between versions to see how the comments were addressed. However, we found during the second semester that comments in the rubric for the first version are overridden by changes to the rubric in the revised document, without a way to track the changes that had been made. Between the confusion of comments in two places and the version control issues, we switched to only providing comments via annotations in the document.

D. Adaptations Based on Feedback

Three levels of difficulty were selected for the design project based on the suggestion by Nilson [2] that higher grades can be earned by passing more assignments or more difficult assignments. None of the students in the fall attempted the standard or basic version of the project even if it was less work, therefore the versions of the project were removed for the spring semester. The advanced project in the fall semester included three deliverables: a proposal, a BMES style abstract, and a scientific report. The base grade in the spring was modified so that an A base grade included earning a pass on all three deliverables, a B base grade was a pass on two deliverables, a C base grade was a pass on one deliverable, and a D base grade was completing (but not passing) all three deliverables.

The pass/fail grades on the pre-lab assignments received the most negative feedback in the fall semester. Several students reported stress or anxiety related to grades on pre-labs since they could not be revised and resubmitted. I thought that this would be manageable since a student only needs to pass half of the pre-labs to keep their base grade. After reminding the students mid-semester that there was room to make mistakes on pre-labs and still pass the course, they were less motivated to attempt the pre-lab assignments at all. Some students seemed very disgruntled after failing early pre-lab assignments for not closely following the formatting instructions. Additionally, based on feedback from the lab staff it was hard to keep grading consistent between graders on the pre-lab assignments. Based on this feedback two major changes were implemented for the spring semester. First, the grading of pre-labs was split by question rather than by section. This improved consistency overall. Second, the pre-labs returned to partial credit. In the spring, each pre-lab assignment was worth 25 points and the assignments were graded with a traditional partial credit system. The modifier in the spring was updated to include the percentage of pre-lab points earned. The spring modifier calculation was as follows:

- Add a plus (+) to the base grade if the student earns
  - At least 85% on the points on pre-lab assignments, and
  - At least 85% on the lab practical exam
- Add a minus (-) to the base grade if the student earns
  - Between 50% and 69% of the points on pre-lab assignments, or
  - Between a 50% and 69% on the lab practical exam, or
  - An unexcused absence from your lab section
- Lower the base grade one full letter if the student earns
  - Less than 50% of the points on pre-lab assignments, or
  - Less than 50% on the lab practical exam, or
  - Two or more unexcused absences from your lab section

The above change required students to complete more pre-lab assignments than in the fall, however, there were no complaints about pre-lab assignment grading during the spring semester.

The workload of the students and staff is another part of the scheme that still needs to be adjusted. In the feedback, students mentioned the cognitive load of managing three different labs (pre-lab, lab, and revisions) at the same time. Some of the workload issues raised by students did not change with the grading scheme, however, the need for revising most labs did change. Students also mentioned that it was difficult to do revisions with long gaps between lab and feedback leading to revisions. The long gaps between labs and revisions were due in part to the grading workload of the staff. In the second semester, more information was provided to the students about how to earn a passing grade on the first attempt of a post-lab assignment. Unfortunately, this additional information did not seem to increase the frequency of passing grades on the first attempt. Further analysis of the types of mistakes leading to revisions of post-lab assignments is planned to improve the clarity of instructions for each assignment.

Since this grading scheme was unfamiliar to most of the students in the course, clear and repeated explanations of the final grade calculation were required throughout the semester. In the fall semester since the scheme was new for everyone including the course staff, these explanations were not as clear as they could have been. Additionally, the calculator spreadsheet mentioned above was not available until mid-semester. In the second semester, some of the staff returned and materials such as the spreadsheet were made available at the beginning of the semester. There have been fewer questions about the grading scheme in the spring semester indicating that some of the changes have improved clarity.

V. Conclusions and Future Work

Specifications grading can be successfully implemented in an undergraduate STEM laboratory course with careful planning and clear communication with lab staff and students. After two trial semesters, I have decided to keep this grading scheme going forward and continue to refine and adapt based on additional student feedback. Future work on this project includes analysis of the post-lab reflections, a review of assignments to identify trends in mistakes leading to failed attempts, and more detailed feedback via a survey and possibly a focus group if needed.

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