New Faculty Experiences with Mastery Grading

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1. Introduction:

One challenge encountered when implementing novel pedagogical techniques is how to handle the methodology on a practical level in the classroom, and how to deal with administrative issues that may arise. This may be especially true for new educators, who may be simultaneously working to establish practical classroom experience. This paper provides an overview of one novel pedagogical practice, mastery grading, and provides experience from a new educator implementing the technique for the first time. This guidance may help alleviate challenges facing other educators hoping to implement this technique and may shorten the "start-up period" associated with trying out new classroom practices. It is hoped that this will reduce fear about impacts on teaching evaluations and increase the accessibility of the method, especially among new tenure track faculty [1].

1.1 What is Mastery Grading

In this paper, the term mastery grading refers to assessment techniques that provide students with repeated opportunities to attempt problems in a given topic area, and allows students to improve poor grades in initial attempts with by demonstrating improvement in subsequent attempts.

The stated purpose of mastery grading is in part to shift the focus of homework from a summative to formative assessment activity. In typical engineering courses, homework assignments are graded once for credit (possibly including partial credit for incorrectness), and returned to the students. This approach does not provide any incentive for the student to address misconceptions or incomplete understanding, at least not until they are tested on the material at a later date. By assigning zero credit to incorrect problems with the possibility of earning full credit upon correct resubmission, mastery grading provides a direct incentive for students to perform active reevaluation of their performance and revisit concepts they failed to complete correctly.

The specific case used by the authors involved application of mastery grading to homework in a sophomore level thermodynamics course, primarily intended for mechanical engineering students. Students were assigned homework in which each problem was corrected for full or zero credit on a right/wrong basis. Instructor feedback was provided on incorrect problems in order to facilitate reaching the correct answer. Students were then given an unlimited number of opportunities to resubmit the homework with no penalty, allowing them to achieve a higher score on the assignment and improve their comprehension.

This paper focuses on the experience of faculty in implementing this technique. We discuss practical considerations encountered that we hope may serve as a guide to future educators considering this approach to formative assessment.

2. Background:

Homework is a commonly used form of assessment in engineering courses. Unlike exams, where student achievement is specifically being tested, homework is often intended to be an opportunity for students to learn concepts through practice. These intentions for assessment may be described as summative and formative, respectively. Formative assessment, the type that best describes the typical *intent* of homework assignments, helps both students and instructors identify achievement and adjust learning activities as needed to address shortcomings [2]. Though the intent of homework is matched by formative assessment, homework that is corrected, graded and returned does not require students to engage in formative activities. Grading provides students with performance feedback relative to their success at correctly solving a problem. Typically homework does not carry an incentive to revisit mistakes and to improve performance, other than in preparation for exams. Adjusting the modality of homework grading may be an opportunity to provide feedback and to ensure that students review and correct their mistakes or misunderstandings. The availability of high-quality feedback guiding formative assessment is known to improve student learning experience [2], [3].

Grading and feedback methodologies exist that attempt to create a more formative homework experience. These methodologies strive to provide not simply performance feedback, but content feedback (i.e. the process attempted in solving a problem). The content based feedback is the information necessary to guide students to improved understanding. Ideally, such a method would also provide an incentive for students to explore the feedback provided and close gaps in knowledge.

One method for providing formative feedback to students is the use of clickers in the classroom. Clickers (or similar devices) can be used to assess understanding of a class of students through the integration of multiple choice style questions in a lecture. Faculty can then adjust teaching based on the class's demonstrated performance. Several studies have shown the positive outcomes produced by this type of strategy [4]. A second strategy is development of automated homework assessment systems that provide feedback based on incorrect responses, and allow for resubmission. These systems have been also been shown by literature to have a positive impact on learning [5].

While both of these approaches are known to provide learning benefits, they do have shortcomings. Clicker-type devices are limited to multiple choice answers, a requirement that curtails the complexity of questions that can be asked and the depth of responses that can be probed in student knowledge, and these system typically only work in the classroom and not outside of the classroom. Automated homework assessment systems require significant development on the part of faculty, or in cases where commercial tools may be available, require financial resources for access.

In the present study we investigate an alternate approach for feasibility in relatively small classroom sizes (under 30 students). The alternative is based upon the intent of automated homework assessment systems, but instead utilizes manual instructor grading of homework, provision of feedback, and allows students opportunities for resubmission of work. A similar strategy was employed for exams by Sangelkar et al. [6], who showed students were more likely to address feedback using their approach.

3. Methodology

In this study, mastery grading for homework was implemented by two instructors in sophomore-level engineering courses. One instructor had familiarity with the technique (Instructor A), while the other was a novice (Instructor B). Instructor A implemented mastery grading in a Dynamics course, and used traditional grading in Thermodynamics and Strength of Materials. Instructor B implemented mastery grading in Thermodynamics at a different campus. The same homework assignments were used in both thermodynamics courses in order to make a direct comparison between the two grading methods. Data were recorded to compare the time required for grading using each method. Qualitative student feedback was also collected via followup interviews with a small number of students. Instructor B maintained a journal of the experience implementing mastery grading for the first time, and containing observations about challenges encountered throughout the process.

In the thermodynamics courses, fifteen homework sets were assigned over the course of the fifteen week semester. One homework set, consisting of 4-5 problems from the textbook [7], was turned in each week. Virtually all submissions were made in the form of handwritten calculations. The mastery grading technique can be summarized as follows:

1. Problems from the course textbook were assigned to the class and due on a weekly basis. Most assignments consisted of 3-5 open ended problems. At the assigned due date the assignments were collected by the instructor.
2. Each problem was assessed separately with full points assigned for complete, correct answers and zero points for incorrect or incomplete answers. Students receiving zero points on a problem were given feedback to assist in reaching the correct solution.
3. Assignments were returned to students within one week. Students were permitted to re-solve problems on which they received zero points on a separate sheet of paper, and resubmit it attached to the original graded assignment. Resubmissions were graded and returned to students as in step 2.
4. Students were permitted to continue the resubmission cycle until all problems were correct, or until two-weeks had passed from the initial due date. Only the final scores on assignments were used in computing final grades, meaning that students were not penalized for initially incorrect answers that were corrected on resubmission.

During the first course meeting, the method detailed above and in the course syllabus was described verbally to the students. During this description, the motivation behind adopting the method was also discussed. Detailed discussion of the quantitative data collected can be found in a companion paper [8], however, a brief summary is provided here. Mastery grading was found to slightly increase the amount of time required for faculty to grade assignments, due to the need for re-grading. Students indicated that they spent more time on the homework, and that they felt they learned more with the mastery grading system than they would have with a traditional grading system. Homework grades were initially found to be lower in mastery grading sections because of the all-or-nothing grading system, but students were able to correct almost all errors within two resubmissions and final homework grades were found to be higher in the mastery grading sections. Qualitatively, student response to the mastery grading experience was largely positive.

Subsequent work is planned to provide additional quantitative data relative to this implementation of mastery grading, including both quantification of student reactions to the method and on student achievement on learning outcomes. As this was the first time that both instructors had offered the course, no comparative grade data were available, nor was it possible able to assess student performance in subsequent courses. However, we anticipate that this mastery grading approach, as with similar techniques discussed in the literature, will enhance student learning and make homework a more formative activity.

This paper primarily deals with sharing faculty experience developed in this implementation as recorded in the journal by Instructor B. We also provide suggestions to new engineering educators who are interested in trying mastery grading in their courses to help them deal with some of the challenges encountered.

4. Practical Experience:

Planning to use mastery grading in this course was initially daunting and there were a variety of questions or concerns that the faculty had prior to implementation:

- How will students receive this method?
- Will problem selections be suitable?
- Will administrative problems (e.g. cheating) be exacerbated?
- How can faculty answers to homework sets be provided?
- How will it affect the time commitment on faculty and students?

Some generalizable guidance can be provided from the authors' experience implementing this technique.

4.1 Presenting the Technique to Students

On teaching evaluations, students often cite a need for fairness in grading systems. Perception of fairness is also related to student retention [9]. One initial concern expressed by the faculty implementing mastery grading was how students would react to this grading approach from a fairness perspective.

Faculty expected that a system that on the surface appears to require extra time and work would be met with some resistance, and would be perceived as unfair by students who already felt overloaded. Additionally, the method is "new" to students and may prove confusing at first glance. In the end however, students indicated that they felt the mastery grading system was fairer than the traditional partial credit grading system because it de-emphasized disputes over points taken off for specific errors. Suggestions to help enhance the perceived fairness of the mastery grading system, as determined through experience by the authors, are as follows:

- We can recommend that assignments be graded for mastery on a per-problem basis, rather than for mastery of an entire assignment and that students not be asked to repeat large sections of a problem that are already correct. These features of the mastery grading implementation used here were described in qualitative student responses as reducing repeated work. Students did not mind making corrections to their incorrect responses, and found the need to only repeat incorrect portions as reducing "busy work." Following the semester, many students even identified the fact that they were able to make up missed points in this way as a positive motivating factor toward homework completion.
- We recommend focusing on the learning benefits when presenting the grading method to the students. As discussed in section 3, the presentation of the method emphasized not only the mechanics of the system but also the motivation behind implementing the system of mastery grading and the opportunities to earn back missed points. Having couched the technique in this way, the initial response from students was not a negative one. In the post-semester teaching evaluations, several students mentioned that they felt the experience was positive on the whole. So taking time to encourage a positive initial response seems to have encouraged a positive overall student perception of the method.

4.2 Planning Problem Sets for Mastery Grading

Due to the nature of the mastery grading approach, there are several difficulties that were encountered during grading of assignments. Specifically, problems that were subjective in nature, such as defining terms, were found to be difficult to apply mastery grading on. The difficulties caused an unexpected increase in the time spent grading assignments, and in some cases, they also led to additional student commitment on a problem with little learning payoff.

One example of a difficult-to-grade problem type was conceptual problems with short answers. Some specific examples that were found to be challenging were 1) a problem in which students were asked to label energy flows as into or out of a thermodynamic system and 2) a problem where students were asked to draw arrows on a sketch indicating the energy flows. In principle,

when applying mastery grading, the instructor should provide sufficient feedback to guide students from incorrect work onto the right track. When grading the problems described, it was found to be difficult to provide guiding feedback without simply giving the answer. Additionally, the lack of "work" shown on conceptual problems can make it difficult to identify the source of the student's misconception and direct them correctly. For example, if a conceptual true/false question is marked wrong, students do not need to engage in formative activities to obtain the correct answer.

Additionally, in at least one case, student mistakes were characterized by the instructor as failure in "understanding what the problem is looking for." Even when trying to anticipate ambiguous problems from the textbook, several such confusing problem statements were still encountered in this mastery grading pilot. One such problem required multiple resubmissions by students, though interpreting the resubmissions created doubt as to whether additional learning was taking place during the process. It seemed that students understood the concepts from the beginning, albeit failed to interpret a confusing point related to the language used in the problem statement.

A second category that was difficult to grade was problems that could be completed without showing much work. An example in this case was a problem asking students to convert between SI and Imperial units. Many students used calculators or other unit conversion tools to obtain the answers without showing work, again making it difficult to provide directed feedback toward a solution. This problem was alleviated during the semester by adding the stipulation that problems that did not show work would be marked wrong out of hand. Besides allowing mastery grading to be applied more consistently from an administrative perspective, this encouraged students to engage in a generally favorable practice for calculations.

In response to these challenges, we recommend avoiding true/false, multiple choice, and conceptual problems in the mastery grading portion of the assignments, which should rather focus on procedural problems that will produce concrete, numerical answers. When problems that might have produced confusion are encountered unexpectedly, we recommend that faculty be flexible and err on the side of common sense, keeping the purpose in mind. If repeated resubmissions are likely to only create work without producing formative learning activity, it would be better to give students the benefit of the doubt rather than rigidly adhering to the mastery grading approach. While we remained rigid in this study to maintain consistency, this philosophy could also be applied as a time saving approach to minor mathematical errors, in which transcription or calculation error produced an incorrect result, while conceptual understanding is still demonstrated.

4.3 Administrative Issues

Concerns related to academic honesty and the potential for cheating among students are a reality of all faculty assessment efforts. It is also true that students walk a fine line between copying and collaboration, a distinction that can be difficult to detect in homework style assessment and may

be overlooked by faculty. Neither the faculty journal nor the student follow up interviews allow conclusive statements to be made regarding the interplay between mastery grading and student academic honesty. Anecdotally however, some students indicated that they felt that traditional, once-and-done grading approaches incentivize cheating relative to mastery grading in that the stakes for the assignment are higher. Faculty observations noted that some students admitted to using online homework help websites to get solutions for the problems, which may result in incorrect answers and has been shown to negatively correlate with exam performance [10]. Based on the experience gained in this study, mastery grading cannot be said to help or hurt when it comes to issues with cheating. Further study may be warranted into the anecdotal claim that some students felt less pressure to cheat because of the opportunity to resubmit work.

One administrative issue that did need to be addressed in the present experience was late submission of assignments. The instructors initially overlooked this issue due to the opportunities for resubmission that were offered, however as it began to become an issue during the semester, a policy was adopted. In deference to the stated purpose of mastery grading, as to create opportunities for formative assessment, a permanent penalty was instituted for students who submitted work late. Students whose initial submission was after the deadline for the assignment were given a penalty equivalent to one incorrect problem on top of any problems that they got wrong, and this penalty was retained after resubmissions. While the specifics of such a policy could be tailored to match instructor preference, we can recommend that faculty implementing mastery grading consider the late submission policy they wish to adopt in order to ensure that even with resubmissions, students complete and turn in homework assignments.

A second administrative area of concern was how to provide students with faculty solutions to the homework. While this study is unable to make comparative judgments on options for providing solutions, we can comment on the experience using the method chosen. As discussed previously, in this study, we used a two week resubmission window, after which faculty solutions were provided. The journal observations indicate that this did not appear to significantly impact the ability of students to successfully complete resubmissions. An overwhelming majority of students achieved completely correct assignments within two resubmissions. Additionally, even in the absence of the need to provide faculty solutions, the resubmission window may be viewed as an opportunity to enhance the formative nature of the activity by maintaining proximity between the practice and the learning.

4.4 Time Commitment

As stated, the companion study of mastery grading [8] showed a slight increase in time required for grading assignments. Some guidance can be provided to limit these impacts. A simple improvement can be made by requiring a standardized format so mistakes can easily be identified and work interpreted. Many faculty already require this type of homework format, so this is not really a special case practice. With this requirement goes the need for students to show

all their work. This was found to be very important in cases where mistakes are made by students and interpretation is required to provide suitable feedback.

A second method that was used to reduce the time required for grading was allowing students to begin from where they made a mistake. In this study, within the feedback, we notated “start from here” on problems that were partially correct. On a similar note, we also found that many students made the same mistake, or the same category of mistake. When providing feedback for that type of mistake resulted in long explanations, we found it convenient to duplicate (photocopy or typed solution) the explanation to save the need to re-write the guidance several times. Lastly, in-class time can be used to address problems where mistakes were made by a large number of students to save time on writing the same feedback. This also has the benefit of allowing time for student questions about topics that have been demonstrated to be confusing by the large number of incorrect answers.

4.5 Ancillary benefits

Several non-academic benefits to mastery grading were described in the instructor journal from a faculty perspective. Since fairness concerns are cited highly by students, faculty members may feel pressure to create grading systems that are perceived as objective. The faculty member expressed a satisfaction with mastery grading in this regard. The concrete, objective standard of grading offered by mastery grading was described as reducing pressure by removing the need to make decisions about how to fairly assign partial credit. While the class sizes in this study were small, we hypothesize that this factor may be particularly useful in larger courses that make use of multiple teaching assistants and need to utilize grade norming.

Additionally, by providing students the opportunity to improve their scores, mastery grading reduced the pressure to consider grade inflation techniques (e.g. extra credit) or “curving” to tune the standard level of performance. Students were inherently provided opportunities to “inflate their grade” by demonstrating mastery of concepts; any poor performance could conclusively be attributed to student choices not to resubmit assignments. This provides new faculty members who are still developing their expectation for level of student performance with an opportunity to do so with the help of objective standards.

5. Conclusion

Implementation of mastery grading orients homework assignments toward formative assessment. While it does require additional time investment on the part of both faculty and students, it also resulted in a positive reception from students and showed other benefits. Faculty members new to implementation of mastery grading kept a journal containing reflections on the process, from which suggestions can be made to other new faculty who may consider implementing the technique.

- When presenting the method to students, emphasize it as a technique to enhance learning. When doing so, students were positive about the method.
- Remember that the purpose of mastery grading system is for students to address errors in their work and form a better understanding. Avoid making students repeat work that they have already successfully completed.
- Procedural questions with clear numerical answers that result from several steps of calculations work best with the mastery grading system.
- Faculty should establish a clear plan on how to address administrative concerns like collaboration/copying on homework and late submissions in advance and should clearly communicate these expectations to the students.
- Requiring students to attach corrected problems to their original submission can simplify the process of scoring resubmissions. Time savings can also be achieved by allowing students to continue from the point in a problem where their mistake occurred.

Mastery grading on the whole can improve student learning, and if done correctly it can be an easy way for new engineering educators to establish a fair system that encourages student growth. It is hoped that the guidelines provided above can help new engineering educators seamlessly integrate this innovate method into their classrooms.

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