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Work-in-Progress: Implementation of Standards-based Grading in a Mass Transfer/Kinetics Course

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Abstract:

Standards-based grading (SBG) is an alternative grading technique where grading is based on student demonstration of specific learning outcome (standards) mastery. While a traditionally graded course may contain several high-stakes, high-stress exams throughout the semester graded with partial credit, an SBG course instead allows for students to retry learning outcomes where they have not yet shown proficiency. In short, the focus in SBG is student learning and demonstrated expertise of standards and not competition between students or a fight for enough partial credit to simply pass a course. Despite the increasing popularity of SBG in primary and secondary schools and mathematics courses, SBG has not been utilized as often in higher education engineering courses.

This paper presents the implementation of SBG in an upper-level core mass transfer/kinetics class taught to two different engineering majors (N = 30 students). Previously, students were evaluated via high-stakes, highly weighted quizzes (approximately one each month) and a final exam graded with partial credit. In the redesigned SBG course, students were evaluated on fifteen distinct learning outcomes ('course metrics') via pass/no pass or pass/revise/no pass quizzes administered approximately weekly, plus one course metric that evaluated students based on their in-class participation and completion of homework. Students had the option to retake quizzes for a set number of course metrics at designated times throughout the semester and during the final exam period of the class; a retake tests the same learning outcomes, but with a different question and prompt to solve. Student final course grades were based on the total number of course metrics ultimately passed throughout the semester.

This paper additionally summarizes initial student feedback collected in a mid-semester formative course evaluation and key focus group results on student perceptions of the course throughout the semester, perceptions of their own learning, stress levels throughout the course, and how students prepared for and took quizzes. Overall, this paper provides an example of transforming a traditionally graded core engineering course into a SBG course, including student perceptions and feedback.

Introduction:

As instructors, we are required to provide end-of-the-semester grades for our students, which ideally correlates with student learning and achievement in the class. Typically, students receive a numerical score for each assignment, quiz, exam, or other assessment throughout the semester, and the sum of these scores leads to their final grade at the end of the semester ('points-based grading'). Many of these assessments, like quizzes and exams, are weighted heavily and can be a cause of stress for students [1]. Standards-based grading (SBG) provides an alternative method for grading to conventional points-based grading. In SBG, the instructor identifies a series of learning objectives or outcomes ('standards'); students are then assessed on their proficiency for these standards with their final course grade directly linked to the number of standards they have met or completed by the end of the semester [2]–[5].

While there are no one-size-fits-all requirements for implementing SBG, practitioners typically utilize the following key principles [2], [6]:

1. Students receive assessment feedback to understand which standards they have not yet achieved
2. Students have multiple opportunities to demonstrate their proficiency on a skill or standard
3. Student final grades are based on their proficiency of learning outcomes, or standards

In short, the focus in SBG is on student assessment with instructor feedback, student review and practice, then re-assessment until students achieve competency, or mastery, of the material [7]. SBG has historically been utilized more in primary and secondary education and in select mathematics and non-engineering post-secondary courses [2], [4]–[6]. However, SBG has been utilized in some engineering post-secondary courses, including in a thermodynamics course [8] and a materials course [9]. In the thermodynamics course, the author found that the class GPA was higher using SBG than with traditional grading; further, in both these courses, students felt that SBG was more conducive to learning and that they preferred SBG over traditional grading [8], [9].

Motivation:

The School of Chemical, Materials, and Biomedical Engineering within the College of Engineering at the University of Georgia houses two separate engineering majors: biological engineering and biochemical engineering. The core curriculum for both majors include Mass Transport and Rate Phenomena, a three-credit-hour course that covers biological and chemical kinetics, macro-scale mass transfer (i.e., material balances), and micro-scale mass transfer, as well as fundamental engineering calculations (i.e., unit conversions) required to solve more complicated problems in the class. Historically, the class has been taught and graded in a traditional manner, namely via lectures and with periodic high-stakes summative assessments (four quizzes throughout the semester and a final exam). This course, like other engineering courses taught at University of Georgia, did not have mid-semester assessments, such as midterms, scheduled outside of class. Rather, mid-semester summative evaluations were assessed within the class periods themselves, which typically run for 50 minutes three times a week for a three-credit hour course.

As the instructor for this course in Fall 2022 and Spring 2023 (N = 67 students total), I noticed several themes emerge from students during the semester and during end-of-the-semester student evaluations:

1. Large numbers of students were overwhelmed by the breadth and depth of material covered in the class
2. Students struggled to connect the lectures, which left little time for example problems or in-class activities, to how they were assessed (solving problems related to the course content)
3. Students from one of the majors had more familiarity with aspects of the course content than the other major
4. Many students struggled with time constraints of a 50-minute summative quiz

5. Many students struggled to grasp material at the time it was first assessed via a high-stakes summative assessment (mid-semester quizzes) but could demonstrate their understanding by the final exam
6. Students, in general, fixated on quiz and exam numerical scores, not on the material that they did not grasp after a quiz or exam

As an instructor, these common themes were unsettling. A common struggle I personally had was covering the required content in lecture format and developing summative assessments that covered all the course content without being prohibitively long. I strongly felt that there was a better method of instruction and assessment that would address these common issues, allow students to learn from their mistakes, decrease the stress students felt with each summative assessment, and allow me to evaluate students on a wider range of questions than I could squeeze into current summative assessments. This paper explores my journey implementing SBG into an engineering core course and its results, including student grades and feedback.

Course redesign:

In the Spring 2023 semester, I was accepted into the Active Learning Summer Institute at the University of Georgia. In May of that year, I joined other faculty members from the university to receive training on teaching pedagogy and to redesign one of our courses to be more active learning-focused in alignment with the university's goals. To address some of the common pain points of the class, I decided to flip my classroom, introducing content ahead of class time via readings and pre-class videos and allowing students to spend class time working in groups on example problems. In flipping my class, I deliberately incorporated *active learning* into the course, which itself has been shown to enhance student achievement [10], [11]. To address the dissatisfaction and downfalls of summative assessments seen in the course, I transformed the grading using *SBG principles*. The first step was identifying the most essential skills a student should possess after completion of the course; I identified fifteen different standards ('course metrics,' or CMs), or areas in which a student should demonstrate their proficiency by the end of the class to achieve an A. These standards loosely fell into the categories of fundamental engineering calculations (three CMs), biological and chemical kinetics (four CMs), macro-scale mass transfer (four CMs), and micro-scale mass transfer (four CMs). An additional CM evaluated student homework completion, attendance, and participation ('participation and professionalism' CM).

Other than the participation and professionalism CM, CMs were originally evaluated via in-class quizzes. Each quiz in a 50-minute period covered 1-2 CMs, depending on length, and were evaluated on a pass/no pass or pass/revise/no pass grading system. The option for a 'revise' was utilized specifically for CMs that covered lengthy questions. A student received a 'revise' if they demonstrated that they set up the problem correctly but either made a mathematical error during their solution (i.e., a 'calculator error' or a mistake during integration or differentiation) or ran out of time to complete the problem fully. Students who received a 'revise' had one week after receiving their graded quiz to fix any errors or complete the problem. Conversely, students who made conceptual errors (i.e., misunderstanding the problem, not correctly identifying equations needed to solve the problem, or not correctly setting up series of equations required to complete the problem) received a 'no pass' as opposed to a 'revise' grade. Students could retake up to two

Table 1: Course grading scheme

# CMs achieved	Final course grade
16	A
15	A-
14	B+
13	B
12	B-
11	C+
10	C
6-9	D
<6	F

CMs three times throughout the semester during quiz retake days in-class, and the three-hour long final exam period allowed students to retake up to five CMs. Ultimately, a student's final grade depended on the number of CMs completed throughout the semester, as shown in Table 1.

Preliminary results:

Mid-semester feedback and adjustments

Eight weeks into the Fall 2023 semester, a faculty member unassociated with this course performed an anonymous midsemester formative evaluation (MSFE) with the students in the course while I was not present. The evaluator anonymized and summarized student feedback for me, including feedback specific to SBG used in the course. At this point in the semester, many, but certainly not all, students liked the modified grading structure as well as having a higher number of lower-stakes quizzes. However, many students wanted more feedback on the grading of each quiz, felt that their grade would be higher with partial credit opportunities on quizzes, and believed that the grading system was unfair or too unforgiving. In addition to this feedback from students, I observed that some course material remained difficult to fit into a 50-minute quiz and that some of the initial CMs were not aligned with the types of questions students had seen on homework and on in-class problems.

I took several actions mid-semester to address these observations and concerns. I had a frank discussion with students about how I graded quizzes and the benefits of SBG. I also shared average quiz and exam grades from previous semesters with the students, including semesters where I was not the instructor of record. I also considered that some course content did not lend itself well to being completed within an in-class quiz. Ultimately, I assessed the final two course metrics via a take-home quiz instead of an in-class quiz, as it became clear students would not be able to complete that caliber of problem in 50 minutes. Students were allowed to work with a limited number of classmates on this take-home quiz and were required to disclose who they worked with and to what extent. Further, I gave students the opportunity to pass one additional metric of their choice outside of class by creating and solving their own unique quiz for that metric. Students chose their own metric, typically one they struggled to complete in a quiz environment, developed their own prompt or question, and then provided the solution to their question; this option provided additional flexibility for students who struggled with time constraints or the quiz format and allowed them a different alternative to complete a metric.

Post-semester focus group feedback

In collaboration with the Center for Teaching and Learning (CTL) at the University of Georgia, I developed an Internal Review Board-approved protocol to conduct focus group interviews with students from the Fall 2023 semester to determine their thoughts, impressions, and feedback on the flipped SBG course in addition to how they utilized course materials. These interviews were conducted after the completion of the Fall 2023 semester and once all students received their grades. While I have not finished a full analysis of focus group interviews, a few clear themes emerged from talking with the students. First, the distribution of stress students felt throughout the semester was different than in traditionally graded courses. In traditionally graded courses, students felt that stress levels tended to climb throughout the semester as they approached a high-stakes final exam. In this SBG course, students reported that they either did not feel stress or that the stress they felt was greatest at the beginning of the semester when they were getting accustomed to the class and its form of grading. However, their stress tapered off as the semester continued and they began to pass CMs. A second theme was that many students felt that they understood the material better due to the SBG structure in comparison to a traditionally graded course. Several students felt that this increase in knowledge persisted over time; more than one student suggested that if I gave them a quiz during the focus group, they could still solve it successfully.

Third, students felt overall that numerical scores, like those from traditionally graded courses, heighten their ‘critical inner voice’ more than the pass/no pass or pass/revise/no pass scores. For some students, seeing a ‘no pass’ on initial quizzes was mentally difficult at first, but that difficulty faded as the semester progressed due to their ability to retake quizzes. Notably, 75% of the focus group students could name the numerical scores they received on their first exam in their introductory physics course in college *at least two years beforehand*, highlighting the lasting impact that numerical grades can have on students. However, the students felt that they could not remember which CMs they did not initially pass in this course the previous semester, which supports that the grading scheme de-emphasized the punitive, critical nature of numerical grades that students can experience and remember over time.

Successes and opportunities for improvement

At the end of the semester, I first wanted to examine how many students passed each metric and when. Figure 1 displays the number of students in the Fall 2023 who passed each CM (other than the metric given for participation and professionalism), divided up into three groups to display the number of students who passed the metric on their first attempt, the number of students who

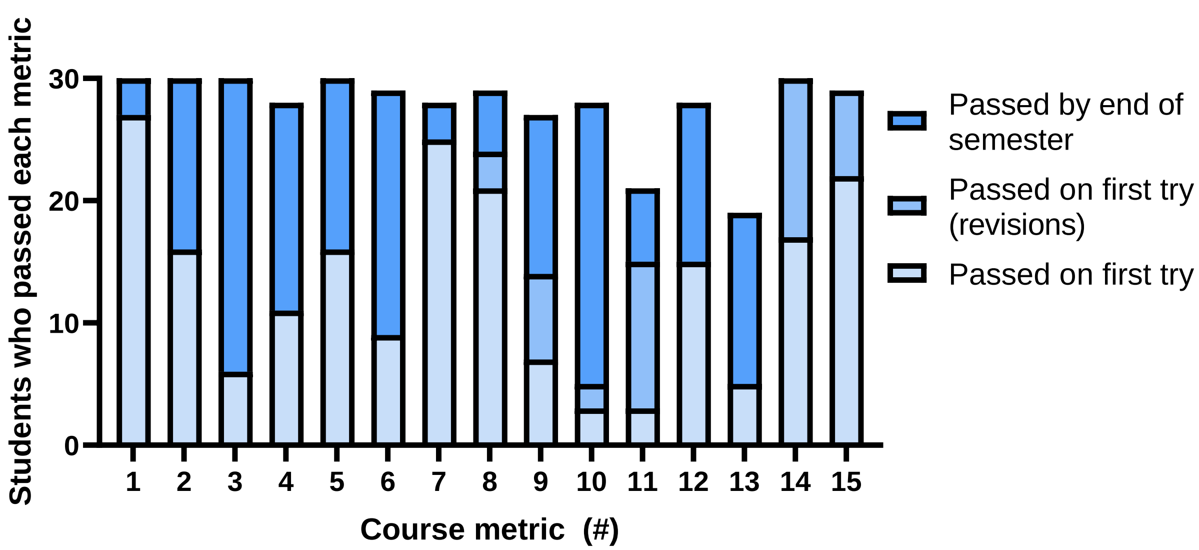

Figure 1: Number of students who passed each CM during the Fall 2023 semester (N = 30 students)

passed the metric on their first attempt after revisions, and the number of students who ultimately passed the metric by the end of the semester via retakes. Notably, there is a large difference between the number of students who passed each metric initially vs. ultimately. This discrepancy is most obvious for CM #10 (steady state material balances with reactions) and CM #11 (unsteady state material balances); while 3 students passed each of those metrics on their first attempt, 28 and 21 students passed, respectively, by the end of the semester.

Figure 2 displays the grade distribution for this course for the Spring 2023 (traditionally structured with traditional grading) and Fall 2023 (flipped, SBG) semesters. There is a clear shift in the grading distribution to higher grades in Fall 2023 and, importantly, a reduction in the DFW rate (number of students who withdrew from the class, or who received a D or F as their final grade). Without context, this shift could be attributed to simple grade inflation. However, students in the Fall 2023 course were tested on *a larger number of problems and content* during their assessments because of the SBG style of assessments; in the traditionally structured course, less content could be assessed via quizzes and exams due to a lack of in-class time.

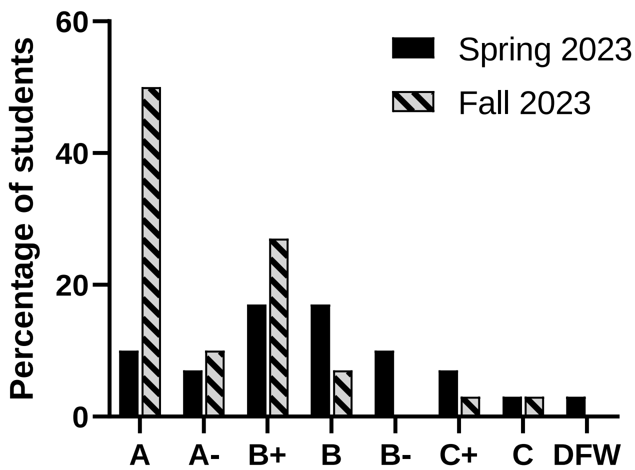

Figure 2: Grading distributions for the Spring 2023 and Fall 2023 semesters

Flipping the classroom allowed not only for in-class problem-solving time with students via contact between the TA, the students, and me, but also allowed more class time to be devoted to assessment. Assessing a wide range of metrics meant that I could evaluate students' knowledge on more content than previously when I only had a few summative assessments each semester. Similarly, directly tying student course grades to metrics passed led to more grading transparency; there was a 1:1 between metrics passed and a student's final grade. Further, shifting assessments from seemingly punitive, final, and unchanging to a 'work in progress' was satisfying as an instructor; while students were often still disappointed not to pass a quiz, I also regularly heard phrases like 'I'll pass it next time' or 'I didn't understand it *yet*' as students left the room. The grading structure allowed for students to learn from their mistakes, knowing that they could pass a metric later with more work and practice.

Despite some tentative successes in this redesigned course, there were several obvious challenges and opportunities for improvement. Flipping a classroom, including developing lecture videos, is itself a large undertaking. Flipping a classroom *and* drastically changing the grading structure required a significant initial time commitment, which should not be understated. When using SBG, it is even more essential to align assessment with course content, which is an area on which I can improve. Further, students need to be provided with information at the beginning of a course about *why* a different grading structure will be used, what its benefits are, and how to be successful in the course. The constraints of the class itself need to be carefully considered. Specifically, there were CMs that were difficult for students to complete within a 50-minute quiz.

SBG has the potential to place each individual metric (or skill) into its own individual silo without giving students the opportunities to synthesize material from different areas of the class. Considering both the time constraints for quizzes and the potential of 'siloing' metrics, it may be beneficial to develop metrics that can be completed outside of the class, potentially in the form of a project. This project could serve to integrate concepts from multiple areas of the class so students are not learning specific skills in a vacuum. Finally, as early-career faculty, I did not have many years of example quiz and exam problems to draw upon for each metric. As a result, I spent considerable time developing quizzes during the semester, especially during retakes when students had the choice of which metrics would be on their quiz. While grading quizzes was initially faster at the beginning of the semester due to utilizing SBG, the time I spent grading did increase as the complexity of questions increased throughout the semester. This phenomenon was particularly true during quizzes where students could receive a 'revise' as I had to determine if students made a mathematical error, warranting a 'revise' grade, or a conceptual error, which did not. Giving students the opportunity to revise quizzes also led to more time spent grading once students completed their revised quizzes. However, long, high-stakes exams also require extensive grading time, particularly when determining how partial credit should be allocated for each question. I believe that some of these time-related challenges will decrease over time once I have a larger portfolio of quiz questions to utilize and have fully established where the revise vs. no pass line falls.

Conclusion and future work:

This work summarized my journey in implementing a flipped, SBG-based classroom for a core engineering course, including its successes and opportunities. Utilizing an SBG course addressed some of the challenges I previously saw in the traditionally graded course, namely that students learned at different rates, that students struggled with stress and time on high-stakes summative assessments, and that traditional assessment does not allow for students to learn from their mistakes. While students initially had many concerns about the course, these concerns were largely alleviated throughout the semester as demonstrated by students' stress *decreasing* as the semester progressed instead of *increasing*.

With such a substantial change to the course structure, there were obvious growing pains and areas of improvement. In the future, I will spend additional time at the beginning of the semester describing what SBG is and how it can be beneficial, plus giving feedback and advice from previous students who passed the course. I also will more critically examine the activities and problems students see in class to ensure they align with the caliber of questions they are assessed on during quizzes. I plan to continue assessing one quiz in take-home format, specifically for metrics that cannot be feasibly completed in class. I will consider adding course metrics that will require students to synthesize material from multiple parts of the class in a take-home assignment or project. Finally, I plan to administer additional focus groups to learn from more students who took the class in the Fall 2023 semester and to conduct a qualitative thematic analysis on feedback from these focus groups; just as students taking an SBG course can learn from their mistakes and change their methods of studying if they are not useful, so should instructors learn from their mistakes and aim for continual improvement.

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