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Who Benefits from Equitable Grading? A Case Study from a Core Electrical and Computer Engineering Course

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Abstract

This *Evidence-Based Practice* paper explores equitable grading practices, how they can be implemented, and the associated costs and benefits. Various strategies to improve equity in engineering classes include allowing retakes, eliminating penalties for missing and late homework, and implementing alternative assessment options. However, concerns often arise about the negative consequences of these changes to assessment. For example, do these practices lead to grade inflation? Does not grading homework lead to students not completing the homework? How do students feel about these changes in grading? Do the practices actually benefit students from underrepresented groups?

In order to answer these questions, three equitable grading strategies (adapted from Grading for Equity by Joe Feldman [1]) were implemented in a sophomore level Electrical and Computer Engineering course: 1) eliminating the 0-100% grading scale, 2) not including behaviors or homework in the final grade, and 3) allowing for retakes on all exams. Because content, homework, and exams are consistent with those from past semesters, comparisons can be made between the grade a student gets using the equitable grading system and a traditional grading systems. This gradebook data, along with demographic data and student surveys, were used to answer the questions and concerns about implementing these grading strategies. Analysis found that students from underrepresented groups were over 7 times more likely to end up with a better grade when using equitable grading strategies ($p<0.01$). Students with better grades were also more likely to have taken advantage of a verbal retake opportunity.

ASEE has made a commitment to improving diversity in engineering, and these grading practices have been shown to help students from diverse backgrounds meet learning outcomes in other subjects/disciplines. By analyzing and sharing data from a core electrical engineering course that used these strategies, engineering faculty may feel more confident in making the switch to equitable grading practices.

Introduction

The American Society for Engineering Education (ASEE) recently reaffirmed its commitment to diversity, equity, and inclusion (DEI) to support engineering students and faculty from all backgrounds. The statement powerfully stated that diverse backgrounds and experiences should be seen as a source of strength and growth rather than something that separates us. However, DEI is not seen as simply a matter of recruiting more students from underrepresented groups; in order to promote DEI, systemic barriers must be eliminated [2]. One of these barriers is the way that engineering programs grade students. Programs no longer need to "weed out" students; rather, they need to support as many students as possible to develop the large number of engineers that our society needs to continue to move forward. However, many of the strategies used to "weed out" engineering students still exist: difficult exams with no retakes, challenging homework sets, and strict deadlines and procedures that must be followed.

In his book, "Grading for Equity", Joe Feldman explores a variety of strategies to eliminate these inequitable grading practices [1]. These practices include allowing retakes, not penalizing behaviors, and allowing students to have time to practice material. Various studies have been done to explore some of these strategies in both K-12 and higher education, but little work has been done to explore strategies specifically in engineering courses. Of those studies, there have been no direct comparisons between traditional grades and grades received with equitable grading practices. Because the students in this study are still completing similar tasks as they would have in a traditional semester, traditional grades can be approximated for each student. By looking at which students receive better grades when these strategies are implemented, information can be gained about what student groups are benefiting. In addition, homework completion rates and student surveys can help paint an even more detailed picture of how these strategies impact students (and what still can be improved).

Background information about equitable grading will be presented, and details about implementation in a Circuits Analysis I course will be shared. Results will be shared in the form of addressing various questions and concerns about equitable grading practices (e.g. grade inflation, student behaviors, and student perceptions) [3]. Finally, a list of recommended grading strategies will be presented. Every course has different situations to consider such as course objectives, class size, and level of students. Therefore, these recommendations are not meant to be prescriptive, but rather to inspire instructors who are hoping to make changes to their grading system to better support learning for students from all populations.

Background

In his book *Grading for Equity*, Joe Feldman breaks equitable grading practices into three categories: practices that are mathematically accurate, practices that value knowledge (not environment or behavior), and practices that support hope and growth mindset. This section will be split into those three sections as well; ideas from Feldman's book will be presented, as well as other research findings, including those specifically from engineering education or other discipline-based education research.

Practices that are mathematically accurate

Practices that are mathematically accurate challenge the idea of a 0-100 scale; why do we have 60 ways to represent failure (0-59%) and only 41 to represent success (60-100%)? In addition, it challenges the ideas of what it means to get a 'C' in a course. Should a student know 100% of the material at a 70% level? Or should they know 70% of the material at at a 100% level? In order to help students better understand what concepts they should be focusing on learning first, many teachers and faculty have implemented standards-based grading, which breaks the material up into concepts and skills that should be met rather than points to be earned. Standards-based grading has been implemented in a variety of engineering courses with positive responses from both students and faculty because of the clear expectations, transparency, and fairness [4,5].

Practices that value knowledge (not environment or behavior)
Feldman argues that grades should be a representation of knowledge rather than ability to conform [1]. Therefore, points should not be awarded for things like attendance and participation, and there should not be punishments for missing deadlines. Grading attendance can negatively impact students who have additional roles outside of school such as a job or care-taking responsibilities, and those students might also have a hard time consistently completing homework on time. One study done in engineering found that there were lots of reasons for poor homework completion ranging from physical or mental health to family responsibilities to work [6]. Homework and attending class can be help students improve understanding of material, but students can still learn material without doing these things. Rather than grading students on their ability to follow the rules of the course, we should only assess them on their understanding of course material.

Practices that support hope and growth mindset
Carol Dweck popularized the term "growth mindset", meaning all people have the capability to learn and grow. A growth mindset believes that challenges, setbacks, and feedback all contribute to the learning process [7]. If we believe that all students can learn, we should not penalize those for learning more slowly. Therefore, practices that support hope and growth mindset include eliminating grades for homework and allowing for retakes.

Rather than homework being a task that students do for a grade, it should be shifted to something that they do for practice. It has been found in engineering courses that homework completion was not strongly correlated to quiz or test performance [8], so it should not be used as a performance measure in the grade. Other studies in university courses found that offering retakes has a variety of benefits. One study found that students reported knowing the material better but being less stressed [9]. Another study found that allowing for retakes in college math courses decreased test anxiety [10]. Another concern with the traditional system is academic honesty, but by allowing for retakes, students might feel less pressure to cheat or copy homework or tests [11]. By placing the focus on the learning, external pressures and factors can be eliminated, allowing students to grow and develop.

Integrating Strategies into a Circuits Analysis I Course

The three categories of equitable grading practices presented in the Background inspired the grading scheme created for a Circuits Analysis I course. The grading scheme is summarized by presenting how each of these three categories of practices were implemented.

Rethinking the 0-100% Scale

Grading in this course is based around tokens; 26 tokens are required for an A, 23 for a B, 20 for a C, and so on. Students earn tokens by answering exam questions, completing labs, and/or completing mini-projects. The token progression was built around Webb's Depth of Knowledge, a learning taxonomy that breaks learning into 4 levels, shown in Figure 1 [12]. To earn a C, students must meet all of the level 2 objectives. Level 3 and 4 objectives could be completed to earn additional tokens.

Depth of Knowledge 1 (DK1) is recall and reproduce. In the case of Circuit Analysis 1, a DK1 skill might be using Ohm's Law (V=I*R) to calculate for a missing current when given a voltage and resistance. DK2 is apply basic knowledge and skills. A DK2 skill might be calculating equivalent resistance of a network of resistors; there is a clear answer but does require some basic sub-skills (e.g. knowing how to identify a series or parallel connection). DK3 is think strategically, which requires a student to complete a problem that isn't exactly like one they've seen. Rather than relying on memory, a student must assess possible strategies and choose the one that is most appropriate. Finally, DK4 is think extensively. Students meet DK4 by applying their knowledge to a totally new scenario.

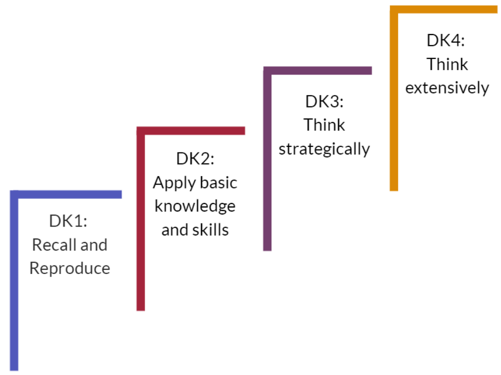

Figure 1: Webb's Depth of Knowledge levels were used to scaffold expectations in the course.

Exams were broken up into two components: core concepts and stretch questions. Core concepts fell under Webb's Depth of Knowledge Level 2; students were completing some procedure. Figure 2 shows an example of a core concept question. A student would need to be able to implement their understanding of resistors in series and parallel to calculate the equivalent resistance of the circuit. Stretch questions fell under Webb's Depth of Knowledge Level 3; students needed to use advanced understanding to identify appropriate strategies and carry them out. Figure 3 shows an example of a stretch question. In order to complete the problem, the student would need to identify that they should be writing node voltage equations (instead of current loop equations), identify the super node, and correctly determine how to represent Ix. Because there are so many ways to set up a circuit like the one in 3, pattern recognition skills alone won't help the students; they need to show understanding of the strategies in order to determine the correct answer.

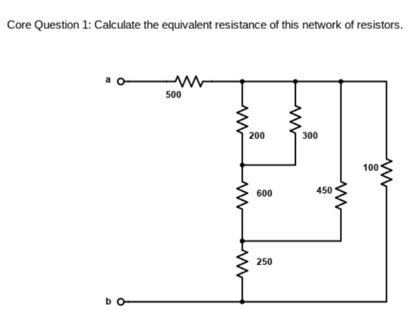

Figure 2: An example of a Core Concept question from an exam where students calculate the equivalent resistance of a network of resistors.

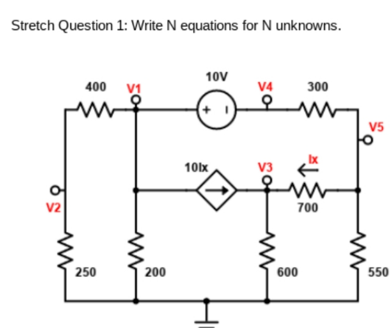

Figure 3: An example of a Stretch Question from an exam. Students write 6 equations for each of the 6 unknown values (V1, V2, V3, V4, V5, V6, and Ix).

Grading knowledge, not behaviors

Because tokens are tied directly to concepts (exams) or skills (labs), no points are awarded for attendance, homework, or participating in clicker questions. Homework was still assigned, and it was communicated to students that they were expected to complete their homework to the best of their ability by the due date each week. However, instead of awarding points, the instructor reviewed and provided feedback on each assignment. The instructor could look for errors at the individual or class level and provide feedback to individual students or review common mistakes and errors in class. Just as athletes have practice before the game, the students could use the homework assignments to show what skills they had mastered and what skills need more work. Because students are not penalized for skipping a question or not completing a question, it is clear to the instructor which skills need more work.

Similarly, students did not earn points for participating in clicker questions each class, but the instructor clearly communicated that this is an expected behavior. In addition, the instructor spent time explaining to students how and why the clicker questions can help their learning.

Allowing for retakes and growth

For all exam questions, either the token is earned or is not earned. To earn the token, the student must show understanding of the whole problem. Some flexibility was given with calculation errors. If the token is not earned, the student can retake the question by either 1) taking a similar question on a later exam, or 2) doing a verbal retake with the instructor. Although this leads to high expectations for the students, it incentivizes them going back to clear up any misconceptions of the material. For example, for the question in Figure 3, a student would be able to write 4 of the 6 equations correctly with no understanding of a supernode. Rather than getting a 67% and moving on, this requires the student to go back and learn that material in order to get the token. If they are successful with their retake, they are given the whole token; they are not penalized for learning material at a slower rate as long as they learn it by the end of the semester.

Students could retake questions either verbally or on the next exam. If they retook it verbally, they could complete the same question, but the instructor could ask follow-up questions to gauge understanding. If they took their retake on the next exam, they got a new question.

Students also could earn tokens by completing mini-projects. These do not take the place of core concepts or labs, but can be used to get students up to an A or B. Example mini-projects included writing definitions for concepts in circuits using only the 1,000 most common words, building an instrumentation amplifier (one of the circuits discussed in class), or making a flowchart to decide which circuit solving strategy is most appropriate.

Student Population

Because this was a case study looking at just one course, students were separated into two groups when looking at demographic data: those from identified underrepresented groups and those not from identified underrepresented groups. This was done to ensure that student identities could not be ascertained and because some demographic groups were not large enough to compare on their own. Of the 70 students, 48 provided demographic information. Of those 48 students, 19 were from underrepresented groups: 7 were female, 3 were non-white, 11 were first generation college students (some students were in more than one group). It should be noted that this course is taught at a medium-sized university in the midwest, meaning the students were predominantly male and white.

Investigating Common Questions and Concerns

The results and discussion will be reported by answering some common questions and concerns about implementing equitable grading practices.

Does this lead to grade inflation?
Two methods were used to look at grade inflation in the course: 1) comparing the letter grade distribution to previous semesters, and 2) estimating "traditional grades."

First, the letter grade distribution was compared to the distributions in previous semesters. Figure 4 shows the grade distributions from the study semester (the top row) and the previous ten semesters that this course was offered. This figure alone presents concerns about our traditional grading practices; the percentage of As given fluctuates from 20% all the way to over 85%. Similarly, the DFW rate (percentage of students who received a D, F, or Withdrawal from the course) varied from about 7% to over 30%. The percentage of As given during the study semester was only about 3% higher than average, and the DFW rate was less than a percent below the average. From this, we can conclude that 1) even traditional grading systems are highly variable, and 2) equitable grading strategies do not necessarily lead to grade inflation.

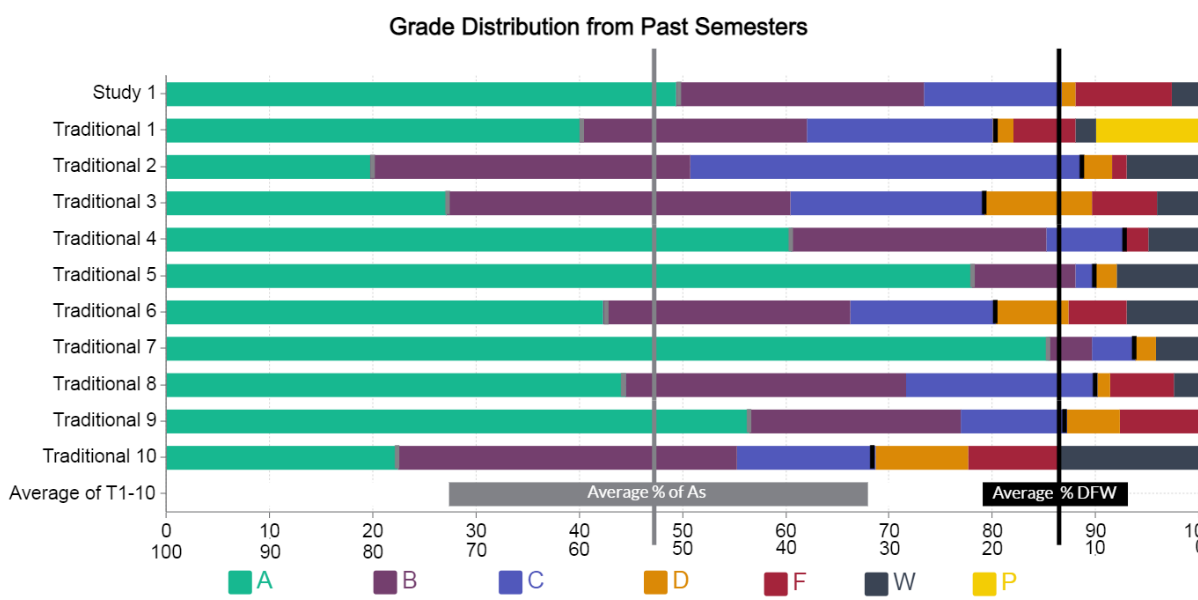

Figure 4: Grade distributions from previous semesters of the course. The top row shows the distribution during the semester that this study was completed, and the other rows show each of the ten previous semesters. The mean percentage of As and the average DFW rate during the ten traditional semesters are shown by the vertical lines, and the horizontal bars represent one standard deviation on either side of the mean.

Second, student grades were compared to estimated "traditional grades". Because the labs and exam questions did not change from previous iterations of the course, estimated "traditional grades" could be calculated for each student. This traditional grading scheme was weighted 20% for Exam 1, 20% for Exam 2, 20% for Exam 3, 20% for Homework, and 20% for Labs. It should be noted that this comparison system is not perfect because students approach earning points differently depending on the grading scheme; for example, students might have studied more for exams if they knew that they wouldn't get the opportunity for a retake. In addition, some assumptions were made in order to calculate the estimated grades: 1) if a student got a question wrong on an exam, they would have received half-credit in a traditional grading system, and 2) all students would have scored 80% on homework. Although not perfect, these assumptions were made in order to be consistent, straightforward, and eliminate the potential for bias when assigning the estimated grades.

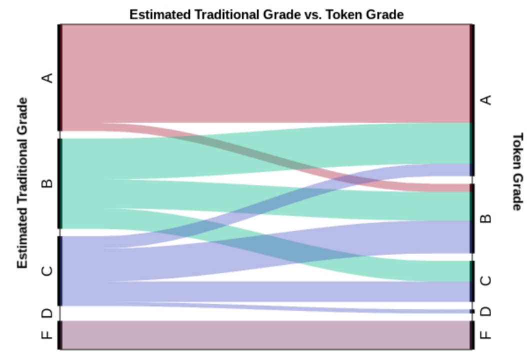

Figure 5: Comparison between the estimated traditional grade that students might have received (left) vs. the graded they received using the equitable grading strategies (right). With the equitable grading strategies, some students received better grades and others received worse grades. However, it should be noted that these differences did not change who passed or failed the course.

During this case study, about 30% of students ended the course with a higher grade than their estimated grade with a "traditional grading" system. However, this grading scheme did not make a difference between those that passed and those that failed the course.

Of the students who got a higher grade with this grading style, 85.7% of them took advantage of the verbal retake process (the others improved their grade by doing retakes during other exams). Because students were required to explain their reasoning during their verbal retake, they had to demonstrate a high level of understanding. This suggests that they did not simply memorize how to do problems in order to earn their token back. Rather, they had to learn the material at a deeper conceptual level.

Does anyone end up with a worse grade?
As shown in Figure 5, 11.4% of the students ended up with a worse grade than their estimated traditional grade. All of these students did not attempt a verbal retake or a mini-project. More work needs to be done to understand if there were limitations that led to these students not taking advantage of these opportunities.

How does this impact students from underrepresented groups?
All students had the option to provide demographic information that was then matched with their gradebook data. The students that provided demographic information (48 of the 70 students) were then grouped into two categories: students from an underrepresented group and students not from an underrepresented group. Students in an underrepresented group were non-white, female, and/or a first generation college student. To assure that no students' identities could be readily

ascertained, these demographic groups were not explored individually, but this could be explored in a larger study.

By using the Fisher Exact Test, it was found that underrepresented groups were 7.5 times more likely to earn a higher grade ($p<0.01$). No statistical significance when looking at the population of students who got a worse grade.

Do students stop doing homework?
To answer this question, homework completion rates were plotted during the course of the semester. Figure 6 and Figure 7 shows three interesting trends: 1) homework completion rates decreased throughout the semester, 2) students that earned an A in the course were more likely to complete their homework, and 3) of the students that earned an 'A' with the token system, the students that would have earned an 'A' with a traditional grading style were more likely to complete their homework than students who would have earned a lower grade with a traditional grading style. Although more work must be done to determine how these factors are related, these findings suggest that completing homework and higher grades are related, but completing homework is not necessary to learn the material and get a good grade when using equitable grading strategies. Because students from underrepresented groups might have other responsibilities that prevent them from completing homework on time, eliminating homework grades can ensure that those students are not being penalized. That being said, the positive correlation of grades and homework completion rates can be communicated to students to help motivate them to complete the work. Although homework completion rates could be a negative consequence of eliminating grading homework, more work needs to be done to better understand how homework completion and learning are related. As seen in [6], reasons for not completing homework vary, so interviews or surveys could further explain the trends seen.

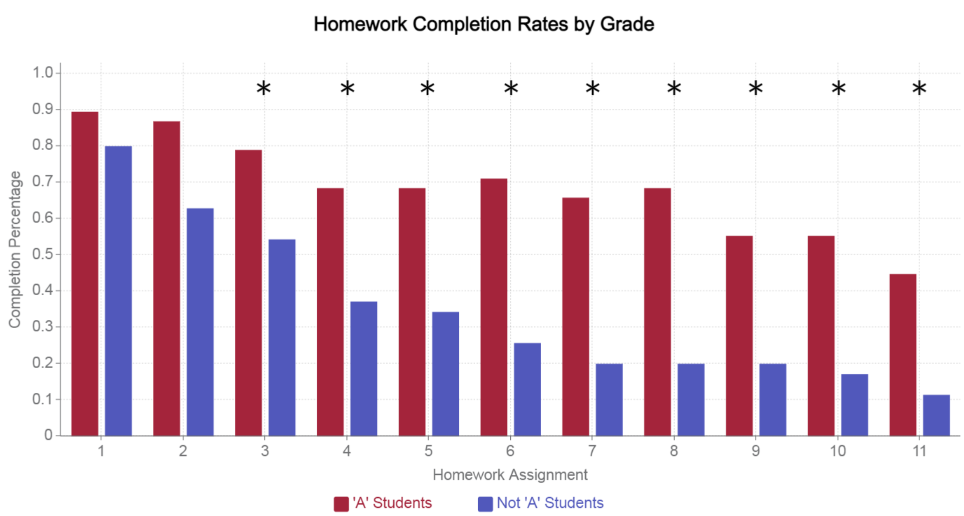

Figure 6: Homework completion rates for students that earned an 'A' in the course versus those that did not earn an 'A' in the course. Although there was no significant difference for the first two assignments, students who earned an 'A' were more likely to complete their homework for the following nine assignments. An asterisk marks that the difference between the two groups was statistically significant ($p<0.05$).

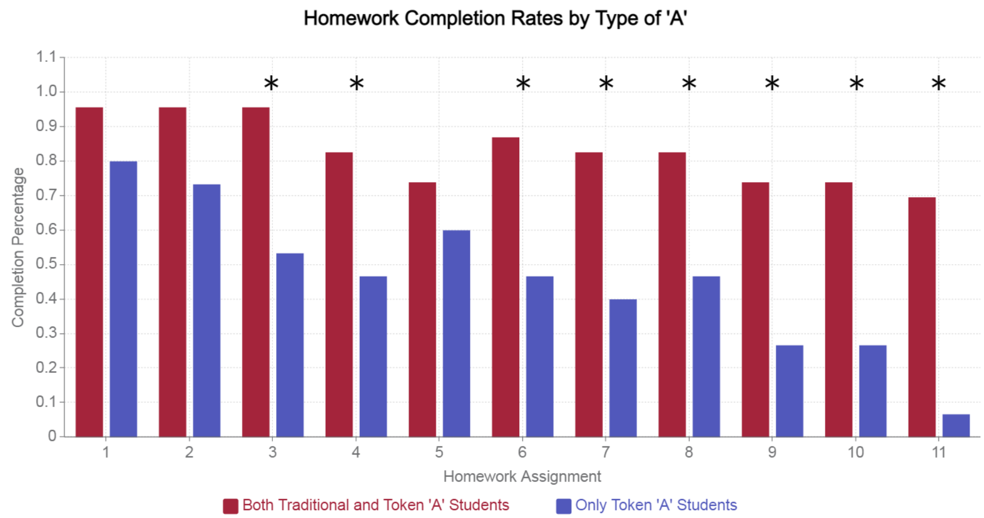

Figure 7: Of the students that earned an 'A' using the equitable grading practices, some would also have received an 'A' in a traditional grading scheme; others would have received less than an 'A'. This graph compares homework completion rates for each of the two groups. Students who would have also earned an 'A' in a traditional grading system were more likely to complete their homework throughout the semester. An asterisk marks that the difference between the two groups was statistically significant ($p<0.05$).

Although not directly measured in this study, it is worth noting that many students showed metacognitive thoughts while doing homework. For example, rather than copying from a friend or from a website such as Chegg if they did not know an answer, they would write a note about what confused them, making it easier for the instructor to identify where students are struggling.

What do students think of the process?

In order to determine what students thought about this process, an anonymous survey was sent out to the students. There were 51 responses to the survey, and these responses were analyzed using emergent coding. One question asked about grading system preference (shown in Figure 7). Two questions looked specifically at likes and dislikes: 1) What did you like about the token grading system? and 2) What didn't you like about the token grading system? Likes and dislikes were sorted into themes, and students mentioning that theme were tallied. Some students identified more than one like or dislike, so they were counted for both themes that they mentioned. Results are shown in Figures 8 and 9.

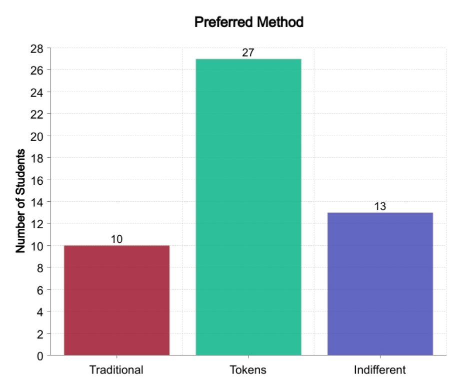

Figure 8: Student responses to the question, "Would you prefer a traditional grading system or the token-based grading system?"

Identified positives included clearer expectations, emphasis on learning, retakes, less stressful, less work, and flexibility. 26 responses were coded as “clearer expectations” and mentioned that it was clear what they needed to do to get each grade, what material they should focus on when studying, and what material they did and didn’t know. The thirteen responses that were coded as “emphasis on learning” mentioned that they felt like they were able to focus more on learning the material rather than worrying about points and deadlines. The eight students that mentioned “retakes” liked that there were incentives to go back and relearn material and that they weren’t punished for learning at a slower rate. Five students mentioned that they were less stressed, one student said they liked it because it was less work, and one student specifically mentioned that they liked that it allowed them to balance their workload better by allowing for flexibility. Three students also said that they didn’t like anything about token grading.

Identified negatives included no partial credit, harder/more work, not being motivated to do practice, being unfamiliar, not getting enough feedback, being confusing, and this model potentially not working in other classes. The most popular code was “no partial credit”, which had fourteen responses. The students that mentioned this said that they wished they would’ve gotten partial credit on their exam questions. Eight students said that this class made them work harder to get the grade they wanted, five were not motivated to do homework/clicker questions because they were not given a grade for these activities, and five just weren’t used to this system. Four mentioned that there was not enough feedback given on exams, two were confused how the grades were assigned, and two said they liked it in this class, but were worried how it might work in other classes that had different learning goals. Nine said they did not dislike anything about token grading.

One change that was made due to these responses was more extensive feedback on exams during the following semester. This was done by creating codes that accounted for common errors and misconceptions, coding incorrect answers on the exam, and directing to students to resources based off of the codes they received. This was a quick way to give more personalized feedback on exams.

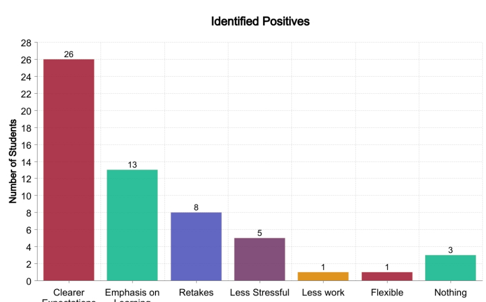

Figure 9: Positives of equitable grading as identified by students. The survey question was open-ended, and student responses were categorized using emergent coding.

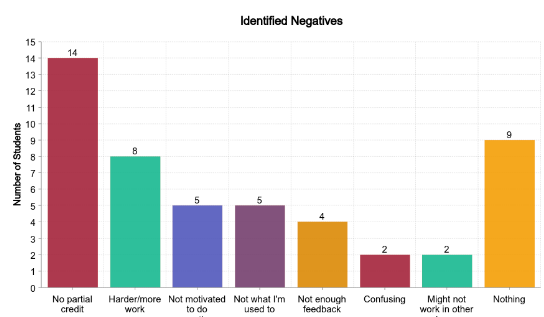

Figure 10: Negatives of equitable grading as identified by students. The survey question was open-ended, and student responses were categorized using emergent coding.

How much more time does this take?
Although this will look different in every class, the extra time spent can be estimated by looking at how many questions were retaken. For this course, conducting a verbal retake was about ten minutes per question, and grading a reattempt at a question also takes about ten minutes per question. In a course of 70 students, about 150 questions were retaken during the semester, leading to 25 hours of work spread throughout the semester split between the instructor who conducted verbal retakes and the teaching assistant who graded the written retakes. Many students waited until the end of the semester for the retakes, so about 10 of those 25 hours were spent during finals week. The instructor was initially concerned about time required, but ultimately found it to be manageable and worth the time.

But do they actually learn more?
This question might be the hardest to answer because grades and test scores are not perfect measures of learning. However, evidence suggests that receiving a poor grade does *not* encourage students to go back and learn material they missed. However, every time a student participated in a retake, the learning process continued past the original exam date.

Strategies: Pick and Choose

Not enforcing deadlines
Although setting deadlines helps motivate students, being lenient with those deadlines ensures that we are not penalizing those that are working full-time, serving as caretakers, or struggling with mental or physical health. Punctuality is important in the classroom and workplace, but people from all industries might need to ask for an occasional extension in order to make sure the final product is at a high level.

Let homework be practice
Rather than pressuring students to cheat on homework to get a grade or punishing them if they don't know something, homework can be used to provide feedback at both the individual and class level. Although homework can be a helpful activity, students can learn the material without completing homework. Therefore, not grading homework doesn't penalize students who might not be able to complete it due to health, other responsibilities, or other extraneous circumstances.

Allowing for retakes
Students learn at all different paces, and allowing for retakes normalizes this. Carol Dweck shows that any student can learn and achieve. If we believe this, we should give students multiple chances to get to where they want to be. In addition, implementing retakes encourages even the brightest of students to return to their errors and improve.

Verbal retakes
Although not always possible or necessary, providing verbal retake times allows the instructor to get a better feel for student understanding and can provide students with practice explaining higher level concepts.

Implementing mini-projects
Mini-projects allow other ways for students to interact with the material without having to take

more exam questions. Students are using higher level thinking by working on projects where there isn't a set answer. It can also help motivate students by giving them autonomy to choose their project and direction.

Structuring expectations using Webb's Depth of Knowledge
Rather than expecting that all students learn all concepts and skills, we can separate lower level concepts and skills that all students should know. Traditionally, a C level student would learn all material to a C level, but that might mean that they are missing fundamental skills necessary for future classes. By making sure that all C level students meet Webb's DK1 and DK2, they are setting the foundation to ensure that they will be ready to use these skills in future courses.

Focusing on concepts rather than points
The ultimate goal is to help students learn, but the trading of "points" as classroom currency can distract from this goal. By placing the importance back on the learning goals of the class, students can develop intrinsic motivation to learn the material. In fact, many professors and instructors are going totally gradeless, or using an "ungrading" framework (see more at [13]).

Conclusions

Learning environments are extremely complex, meaning the outcomes can drastically differ even with the same rules and initial conditions. Therefore, more work needs to be done in order to determine that these findings generalize to other student populations, subjects, and learning settings. Similarly, changes in rules can lead to changes in behavior, so we must be cautious when drawing conclusions about why or how students are behaving differently.

Another limitations of this case study is the population; this was a case study from only one course at a university in the upper midwest. Therefore, further studies will need to be done to better understand the effect of these grading strategies on an intersectional level, especially looking at race.

Another possible area of research is exploring how this affects students in future courses. Students in this course were incentivized to go back and fill in gaps in their understanding, but constant changes in format could be frustrating for students.

However, promising results from this case study illustrate that evidence-based grading practices from other disciplines can also be used in engineering to better support students (especially those from underrepresented groups). Each instructor must implement strategies that fit their course's goals, size, and student population, but this work can be used to inspire and empower instructors who are hoping to support the learning of all students.

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