Work in Progress: Specifications Grading in a System Modeling Course

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Abstract

This paper describes a specifications grading system as applied to a system modeling course composed of mechanical and electrical engineering students. This application was inspired by the use of a specifications grading system in a fluid mechanics course that was presented at the 2022 ASEE conference. The system modeling course adopts some of the same components used by the authors of the original work taking their experiences into account. Specifically, it adopts the mastery grading philosophy of setting high standards that all students must reach to demonstrate minimum competence on exams to pass the course. There is support structure in place, and an incentive system with multiple opportunities for students to demonstrate minimum competency through exam retakes. It also includes modifications and additional learning opportunities for students to earn higher course grades. The paper compares the experiences of the students in this course to those of the original paper. It also includes student and instructor assessment along with suggestions for continued improvement.

1. Introduction

As a faculty member begins to approach a new course, they first determine the learning outcomes the course needs to cover. Then, they build course activities, assignments, and exams around these learning outcomes so that students can learn them and be assessed on their competence. Most students, on the other hand, simply approach a course trying to determine what they need to accomplish to get the grade they desire. [1] If they do receive a poor grade on something, they simply determine how well they will need to do on the remaining assessment activities to achieve a passing grade in the course. It would not occur to most students that they should go back and review the course material to learn the course outcome that was unclear to them causing their bad performance.[2] It seems that many of today's college courses have students simply working toward an average course score, so that at the end of the course they receive a passing grade. Getting caught up working to achieve a certain course average, the students may be missing some of the important course outcomes. [3]

More specifically, examine a typical class with four midterm exams, weekly homework and quizzes that uses a traditional grading system. A student may "fail" to understand the material on two out of the four exams and still "pass" the class if their grades are high enough on the other assessment items. Assuming each exam covers one of four learning outcomes, the student could have passed the class having failed half of the learning outcomes. The grading system used in many of today's college courses may not be adequately ensuring students achieve the learning outcomes of the course.[4]

This paper attempts to address this problem with a modified student assessment system that uses a form of mastery grading called specifications grading. There have been many suggestions for alternative grading systems that include some sort of mastery grading in the past several years.[5,6] However, this system was adapted from some work presented by Brown and Kennedy at the 2022 ASEE Annual Conference[7] and based heavily on a book by Nilson.[8]

Specifications grading attempts to link a passing course grade directly to students achieving a mastery of all of the course outcomes. The system makes it clear to the students exactly what the course outcomes are and how they will be evaluated on each one. There are clear performance standards linked to each course outcome that students must meet if they are to receive a passing grade in the course. The system also provides for multiple attempts to meet the standard of each course objective if the students are not able to demonstrate competence on their first attempt. In addition to setting the minimum standard for passing each course outcome, the system also includes a set of standards that the students can meet to achieve a grade higher than the minimum passing grade.

This system of specifications grading was applied to a junior level course in system modeling. The course included both mechanical and electrical engineering students. There were three sections of the course with approximately 20 students in each section.

2. Specifications Grading System

The specifications grading system used included five assessment tools that were ultimately used to determine the final grades in the course: traditional homework, video quizzes, midterm exams, small individual research reports, and a final project. However, the minimum standards for achieving mastery of course leaning outcomes (and passing the course) were only linked directly to the midterm exams and the final project. The other assessment tools were used to differentiate between students earning the minimum passing grade and those earning higher grades.

Final course grades were determined using a typical 100-point system, and a typical breakdown of 70, 80, and 90 points represented a final grade point of 2, 3, or 4 respectively. However, certain bench marks, based on the course learning outcomes, were required to be met in order for students to earn the required 70 point minimum to pass the course.

The most important benchmark students needed to overcome to pass the course was the midterm exams. Each of the exams was specifically targeted to one of the course learning outcomes, and students needed to demonstrate competence in all learning objectives to pass the course. To accomplish this, the exams together represented 50 of the possible 100 points for the course, and they were earned on an “all or nothing” basis. To earn the 50 points, students were required to get at least an 80 percent on each of the midterm exams. Setting the bar at 80 percent insured that the students were not making major conceptual errors, but did allow for a few simple math or bookkeeping mistakes when completing the exams. Because of this high standard, students were given opportunities to earn the chance to retake exams if necessary using a token system.

The second benchmark students needed to overcome to pass the course was the final project. The final project involved using software to model a real-world application of one of the concepts covered on the midterm exams. The project was worth a possible 20 points, and students were required to earn at least 10 of the 20 points in order to pass the course. By easing the expectation a little for the project, students could pass the course by showing a minimum competence in using the software, even if they had made some initial assumptions that may have oversimplified the problem or made their solution a little questionable.

By meeting the two benchmarks, the students were virtually assured that they would receive the minimum 70 points required to pass the class. An additional 20 points were earned based on homework average, and on online quizzes that were given following video lectures. The homework and quiz performance was also used to earn tokens which represented a chance to retake any exams that the students had failed to achieve the required eighty percent on their initial attempt.

The final 10 points were available for small independent research projects where students explored examples of how the course material was being used in real world design. These research projects had no minimum requirement and in fact were not mandatory for the students to pass the course. The complete grading system is summarized below in figure 1.

Midterm Exams – 50 points (must receive 80% on each exam) Final project – 20 points (must receive 50%) Homework – 10 points (no minimum grade requirement, but used to earn tokens) Video Quizzes – 10 points (no minimum grade requirement, but used to earn tokens) Individual Research Projects – 10 points (no minimum grade requirement)

Figure 1: Specifications Grading System Point Breakdown

3. Implementation of Specifications Grading in a System Modeling Course

To adapt the system modeling course to the specifications grading model, the course outcomes were first defined. For this class, the course outcomes are given below:

1) Develop a mathematical model for physical systems.
2) Develop a mathematical model for electrical system.
3) Set-up and determine the solution to a mathematical model using state space.
4) Set-up and determine the solution to a mathematical model using block diagrams.
5) Set-up and determine the solution to a mathematical model using transfer functions.
6) Use Matlab/Simulink to find system responses

It was determined that the best way to assess if students had indeed mastered these objectives was to include the first five objectives in four midterm exams. By examining the course outcomes directly on an exam, and requiring that students receive a high passing mark on each exam, it could be determined if each individual student had indeed mastered each of the course outcomes. It was then determined that outcome number six could be assessed by assigning a final project. The minimum score on the final project was not required to be as high as the midterm exams to insure correct application of the software. Therefore, the minimum standard was set lower for the final project.

With the objectives and assessment methods defined, it was concluded that high standards must be set for the midterm exams if they were to be used to truly assess mastery of the course outcomes, hence an eighty percent pass rate was set for all exams. Because of the high minimum standard, students were given a chance to earn tokens by completing homework and video quizzes that they could turn in for additional attempts to retake exams if they did not achieve an

eighty percent on their first attempt. This gave students a chance to revisit course material and prove that they had indeed achieved mastery of the course outcomes and earned a passing grade for the class. The final project grading rubric was constructed such that students would be able to show competence using the software even if their overall project grade was closer to fifty percent. Therefore, the implementation of a minimum score was not needed for the final project.

The final step in adapting the grading system was to incorporate motivation for students to concentrate on the homework and lecture videos, as a means to gain a deeper understanding of course material (and eventually pass the exams). To help motivate high performance on homework and video quizzes, a token system was implemented. Students needed to earn tokens by completing homework and video quizzes to give them chances to retake exams that they had not passed. There were six learning modules in the course that each included approximately six homework assignments and two or three sets of videos with quizzes. Students were given a token for maintaining a homework and quiz average above eighty percent for each of the modules. The tokens could then be used to retake exams if the students were not able to achieve an eighty percent on the exams the first time. The students could also use the tokens to replace a low exam or quiz grade at the end of the semester if they did not need to use them to retake exams. A summary of the token system is given below in figure 2.

Activity	**Token**
Begin the semester	+1
Complete a course module with homework and quiz average above 80% (6 possible throughout the semester)	+1
Retake an exam	-1
Substitute 100% for low quiz grade	-1
Substitute 100% for low homework grade	-1

Figure 2: Token System

The specifications grading system, as explained to the students in the syllabus of the system modeling course, is given below in figure 3. The syllabus includes an explanation of the token system at the end.

Exams – 50 points (4 total exams)
If you score over 80% on all exams, you will get all 50 points toward your final grade. However, you **must pass each of the four exams with a score of 80%** in order to pass the course. There will be opportunities to retake exams (see token system below), but you must pass each exam with a score of 80% by the end of the semester to pass the course.

Final Project – 20 points
There will be an individual final project using Matlab-Simulink. The project will be graded on a scale from 0-20. However, you must receive a grade of at least 10 to pass the course.

Homework – 10 points
Your homework percentage will be multiplied directly to the 10 possible points. However, you may use tokens (as explained below) to make up for missed assignments. A token applied to a homework assignment will result in the grade for that assignment being 100%. That homework will also be counted as complete in relation to earning more tokens.

Video Quizzes – 10 points
Videos will be posted on Canvas about every third class period. Each video is followed by a quiz. You will be given 2 chances to take each quiz. Your quiz average will also be multiplied directly to the 10 possible points when determining your course grade. You may also use a token to replace a quiz grade and it will result in that grade being 100% and it being counted complete in relation to earning more tokens.

Individual Challenges – 5 points each (2 possible)
The individual challenges provide a place for you to see real life applications of system modeling concepts. After completing the activity, you will create a discussion post describing your activity. Then, you will comment on others discussion posts. You will receive between 0-5 points for each individual challenge you complete satisfactorily.

Token System
Since everyone is bound to have a bad day or not get something done on time, a token system will be in place to help you make up for problems that occur during the semester. Tokens can be spent to retake an exam, or to make up for not passing a video quiz or homework assignment. Everyone starts the semester with one free token. You will be given an additional token each time you complete a course module with average grades of at least 80% on all homework assignments and video quizzes in that module. Remember, if you earn less than 80% on an exam, you will need to use one of your tokens to retake the exam because you must earn an 80% on each of the exams to pass the course.

Figure 3: Grading System for System Modeling Class

4. Course Details from System Modeling Course

The most obvious difference in this course with the new grading system compared to traditional courses was the exam retakes. To accommodate student and instructor class schedules, the exam retakes were offered during a four-hour block of time during the afternoon on days when a regular exam was already scheduled. For example, if a student had their regular class at 2:00, they would be expected to take the scheduled exam at that time. Then, if they needed to retake an exam, they could take it at 1:00, 3:00, or 4:00 on the same day. It is clear from the student comments that some of them did not like having two exams on the same day,

but it would have been difficult for the instructor to schedule it any other way. There were also three additional days at the end of the semester where students could retake exams if they had not passed them all at that point. During this class time, students who did not need to retake exams were given time to work on their final projects and get help from the instructor if needed.

Obviously, offering the exam retakes did take more time on the part of the instructor. During the first semester of this new system, fourteen different exams were written as opposed to just the four that would have been needed without the exam retakes. Out of a class of 55 total students, there were a total of 63 exam retakes given among 23 different students. This did result in a bit more time writing and grading exams. However, after a semester or two of teaching this class a bank of exams could be created to save the time in writing exams for future semesters. The summation of the grading time amounted to approximately that of grading one additional midterm exam spread throughout the semester. A detailed explanation of the number of students retaking each exam can be seen below in figure 4. Please note that students had many opportunities to retake exams, so not every student that needed to retake an exam would use every opportunity. For example, a student could not pass exam 1, but then decide not to retake exam 1 until the thrid time the retake was offered.

Exam	**Number of Students Retaking**
Exam 1 – Retake #1	18
Exam 1 – Retake #2	12
Exam 1 – Retake #3	2
Exam 1 – Retake #4	2
Exam 2 – Retake #1	5
Exam 2 – Retake #2	3
Exam 3 – Retake #1	11
Exam 3 – Retake #2	4
Exam 3 – Retake #3	1
Exam 4 – Retake #1	5

Figure 4: Exam Retake Summary

Other than the high expectations for exam performance, exam retakes, and the token system there were very few changes from the way this course had been taught in previous years. The course used a flipped classroom style with students watching lecture videos and taking quizzes outside of class. The class time was spent mostly with students working out homework problems in groups of two or three and getting feedback from the instructor. There were also two individual research projects equally spaced throughout the semester. These projects provided links for students to find real applications of system modeling in videos or through small projects. The final project allowed students to pick a dynamic system of their own choosing, determine the mathematical model, and find the time response of the system using Matlab/Simulink.

5. Student Performance

Because this was the first time using the specifications grading system, the instructor felt obligated to make one small change as the semester progressed. After the third exam, there were two students who would not be able to earn enough tokens to retake the exams that they needed to pass the course. At that time, the instructor told the students that if they were indeed able to achieve an eighty percent on each of the exams, even though they did not have the tokens they needed for the retakes, they would receive a 2.0 and pass the class. Ironically, although unknown to the instructor at the time, this modification was included in Brown's original grading system upon which this system was based.[7]

Because students were required to retake exams until their grade was above an 80% for each exam, and because exams accounted for fifty percent of the course grade, the final grades for the class were much higher than usual for this course. The final course grades can be seen below in figure 5 along with a comparison of the grades from a previous semester's class taught with the standard grading scale.

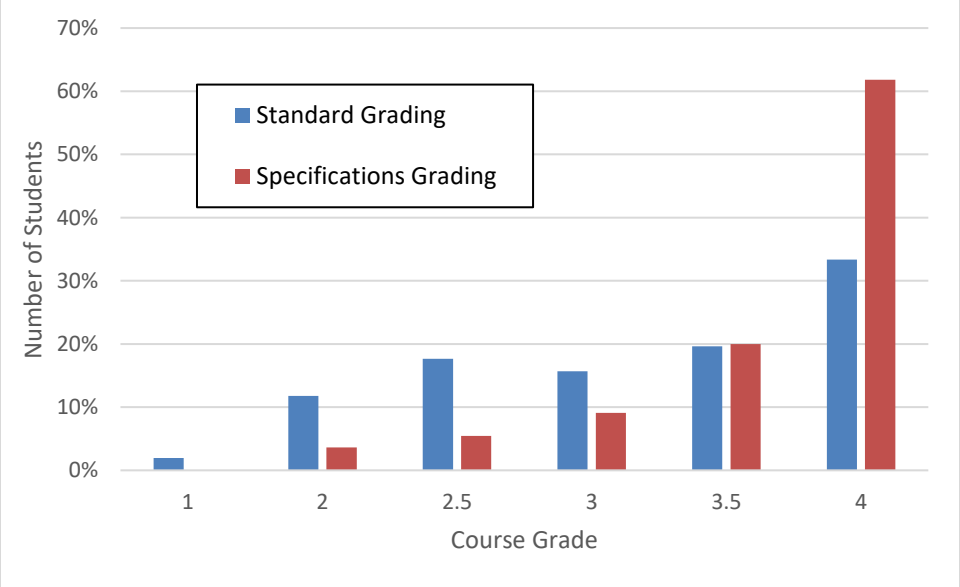
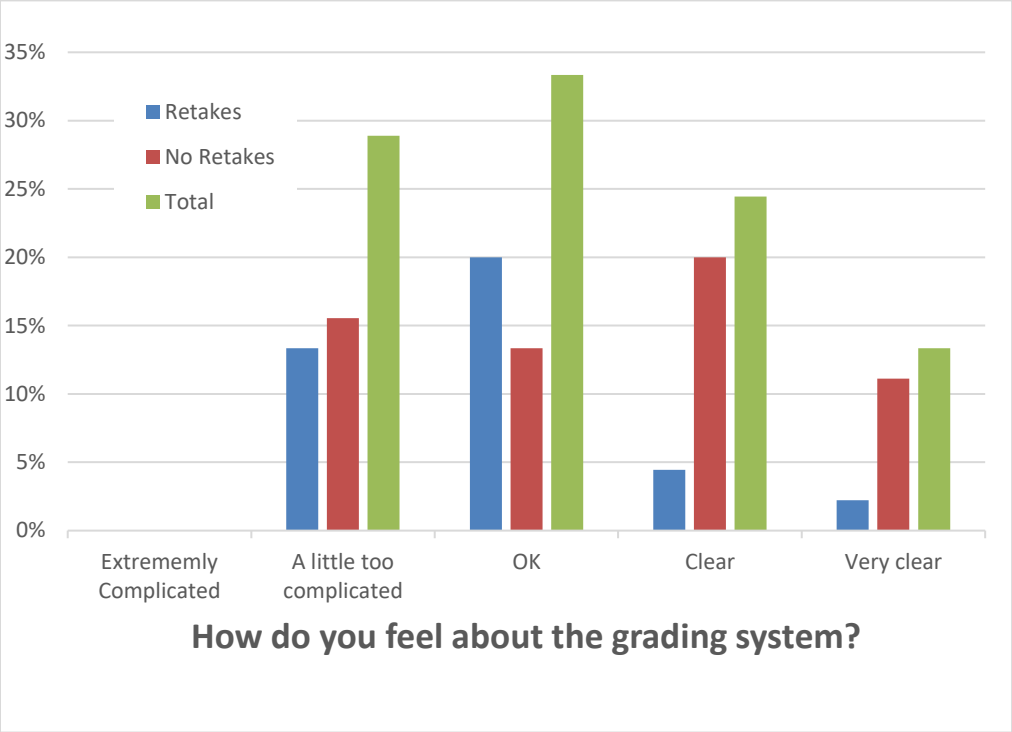


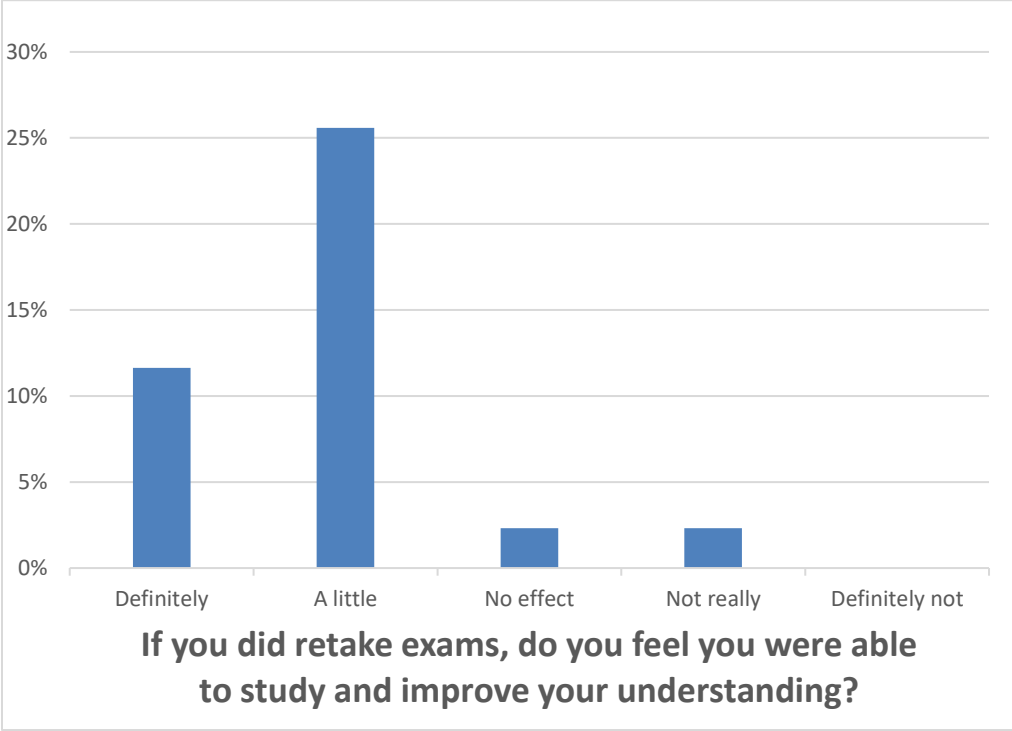
Figure 5: Student Course Grades Using Specifications Grading and Standard Grading

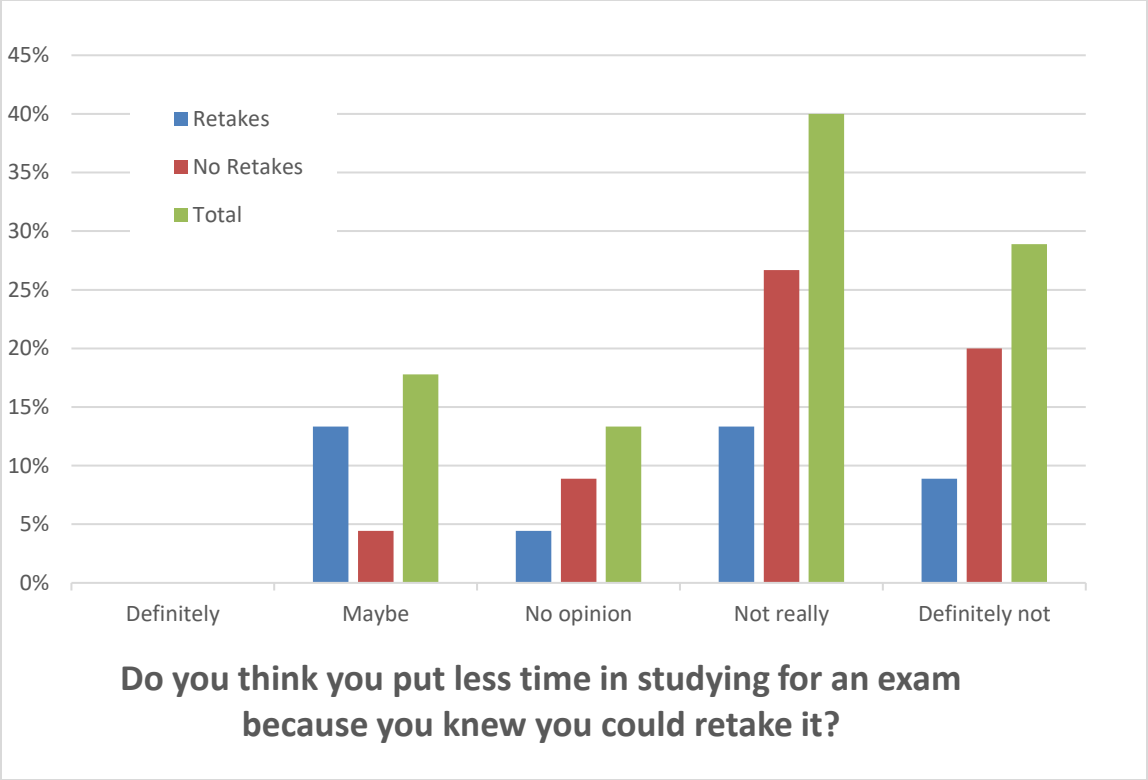
6. Student Feedback

To evaluate the student response to the new grading system, a survey was administered during the final week of the course. The questions were targeted to gain understanding about the students' general feelings, as well as to get an insight into if they thought the grading system effected their performance. Because the surveys were simply meant to get a feel for student reaction to the new grading system, there really was not any detailed statistical analysis performed. When tabulated, the survey data was separated into responses from students who were required to retake exams to pass the course and those who did not need to retake any exams to pass. There was a total of 45 students surveyed in three different sections of the course, and 18 needed to retake at least one exam in order to pass the class. Responses from the surveys are

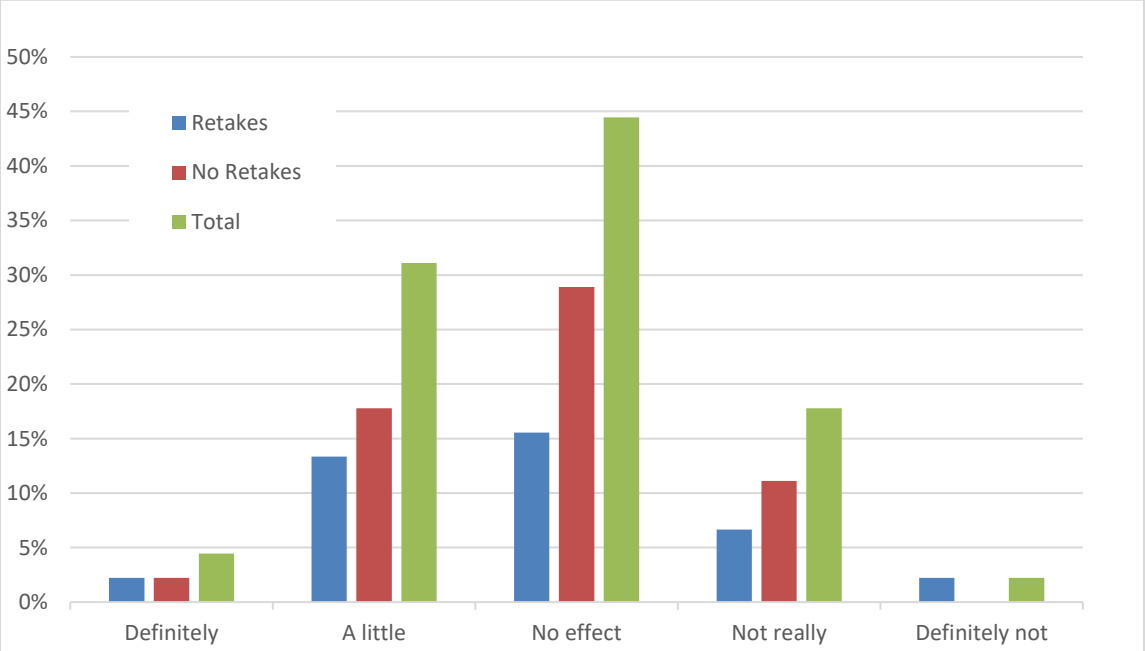
given below in graphical form followed by student comments from both this survey and from the standard college course evaluations.



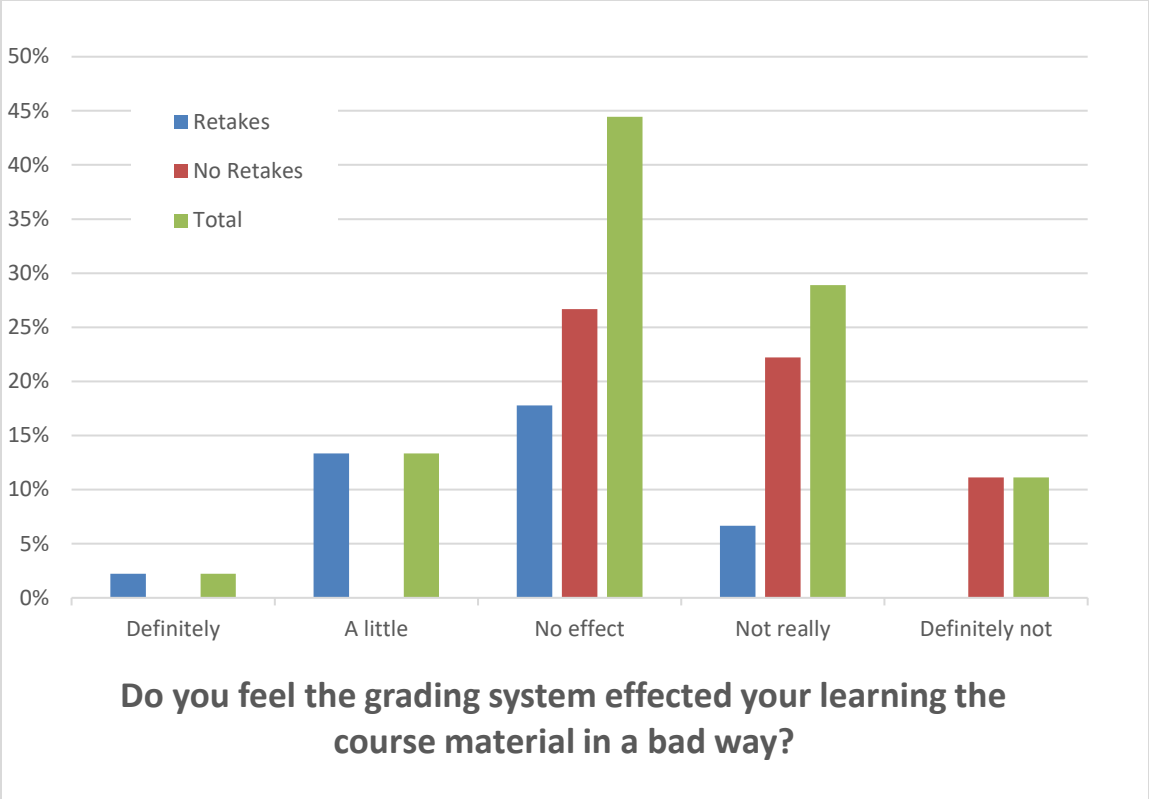




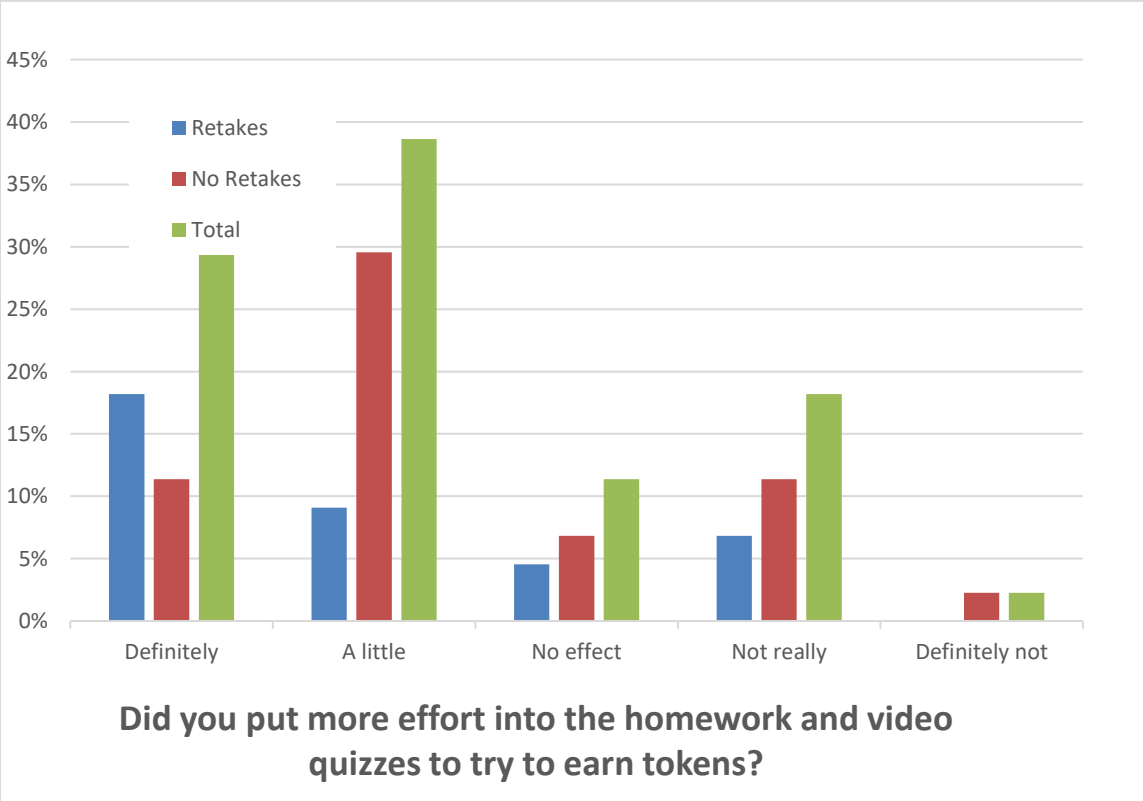
Do you think you put less time in studying for an exam because you knew you could retake it?



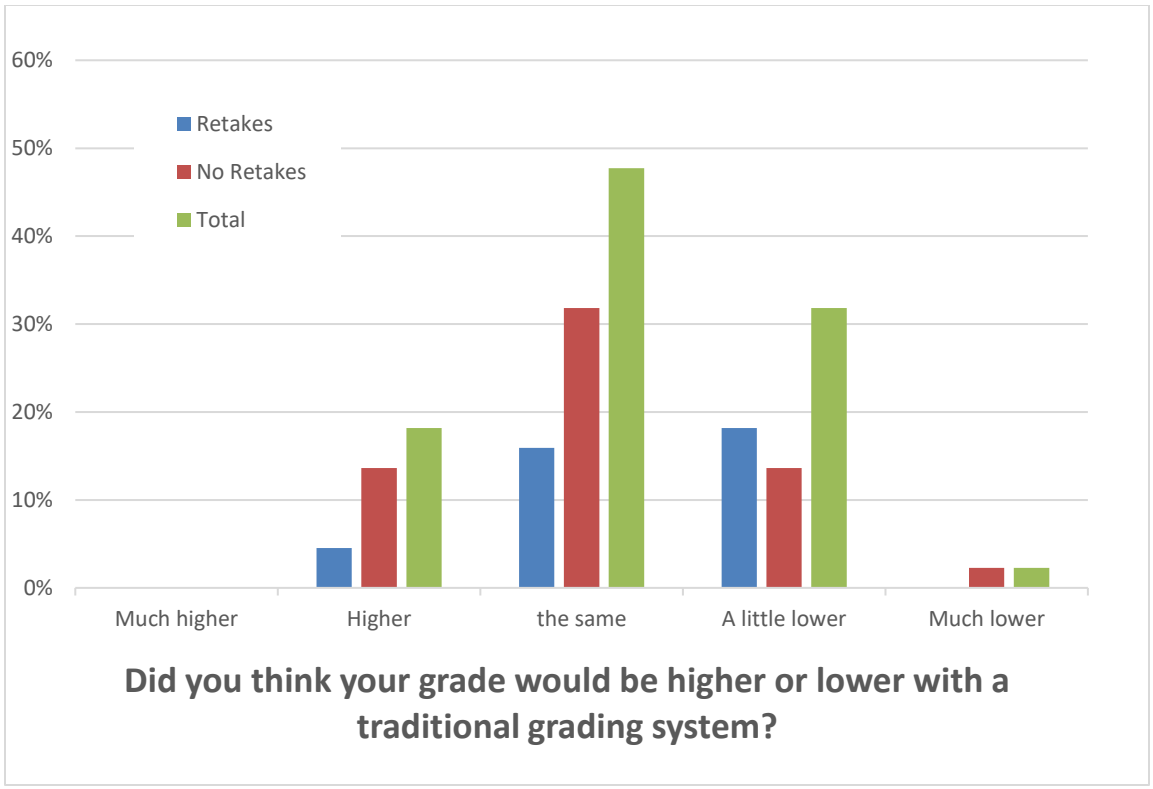
Do you feel the grading system effected your learning the course material in a good way?



Do you feel the grading system effected your learning the course material in a bad way?



Did you put more effort into the homework and video quizzes to try to earn tokens?



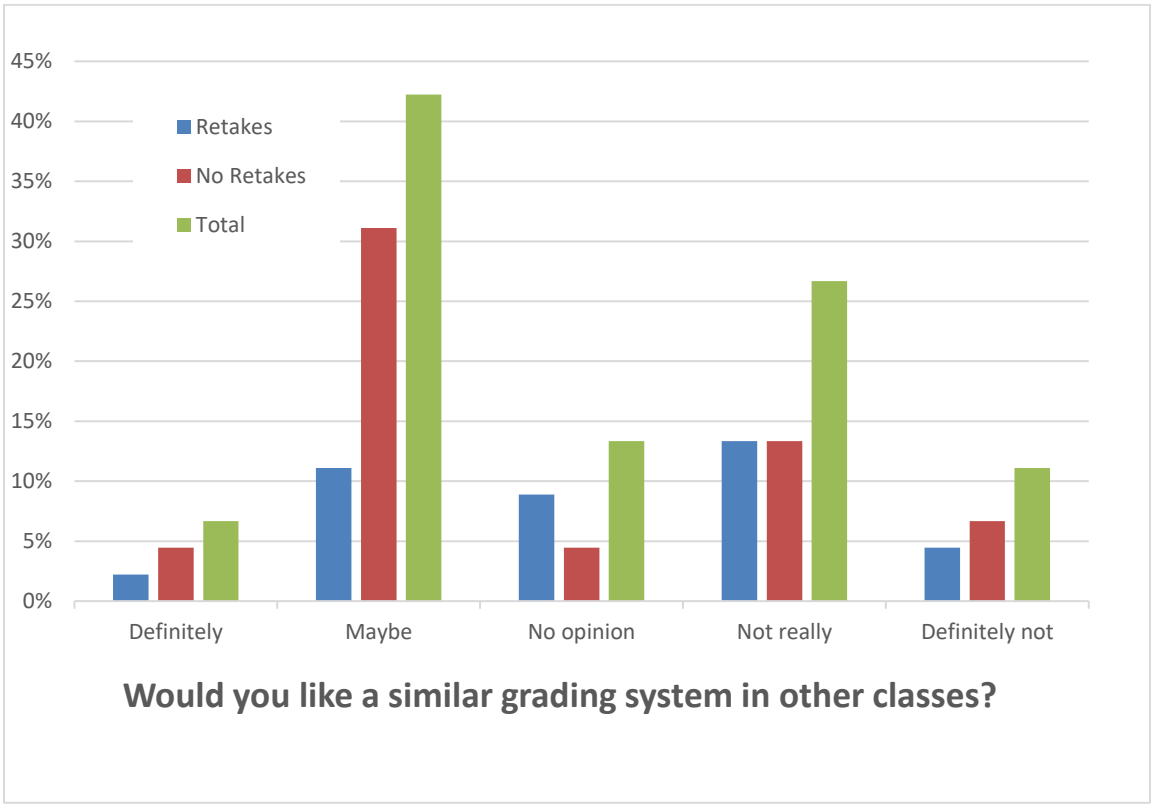


Figure 6: Questions from Student Survey

Additional Survey Comments from students who had to retake at least one exam:

1) Homework grading seems to punish you too much if you don't get an 80%
2) Canvas needs improvement. We shouldn't need to email you for course grades. Inefficient!!
3) Coins are actually really cool.
4) Lower the minimum exam grade, from 80% to 75% or 70%
5) The mastery isn't a bad thing with the 80%s needed but the exams on the same day is a lot of pressure. Maybe a different way of retakes.

Additional Survey Comments from students who did not have to retake any exams:

1) The structure felt perfect for this class.
2) Retakes are good minimum passing grade is too black and white in terms of students grasping the content
3) I think a pass/fail system is ok if the threshold is lower. 80% is a bit too high, at least on exams where one single mistake can mean a failing grade.
4) Use Canvas!! Pass/fail on quizzes makes no sense since one wrong is a fail.
5) Only down side (to me) is that Canvas doesn't reflect actual grade.
6) Trying to understand the grading was brutal. It took a few weeks to understand it. I also appreciate getting an 80% on exams but don't love the concept of not being able to pass without it.

Comments students made on standard college course evaluations:

1) Dr. Kiefer used an odd grading system, which took time to adjust to. However, I felt it both refreshing and rewarding. It encouraged me to strive to be better, but when I had reached a certain understanding my efforts are greatly rewarded.
2) I think the grading system was somewhat confusing at first, but after a while I think we all understood it.
3) The idea that if you got below an 80 on any exam you could fail the course. The only way to not fail is to retake an exam and the only time you can do that is the day of another exam which makes it much harder than the first time you took the exam because now you have to take 2 in one day.
4) The tokens idea was perfectly fine, and any student who actually tries should be able to pass easily.
5) The grading system held the instructor back extremely. He is a capable professor, but the grading system is not.
6) Does not post grades correctly. Students SHOULD NOT need to email professor for correct course grades. Canvas grades do not reflect true standing.
7) Use normal grading system. (stop using 80% requirement for exams and token system)
8) I think the format of the course is great.
9) Make the threshold to fail the class below an 80, or at the very least be able to pass the class with less than a 4.0 in it. Have a system where if you get below an 80 on an exam, instead of failing you get a 3.5 instead of a 4.0 in the course. Tokens can then be used to retake if needed and get a 4.0 if the student wishes.

10) I do not think the token system is great, and it left some people really stressed if they do not perform great on tests.
11) The class had a very unusual approach, but it was high quality nonetheless.

7. Instructor Observations

This was the first time that this instructor had used any type of mastery grading. While there were certainly some students who did not like the system, the course was completed without too many problems or major complaints. As you can see from the student comments, many did not like that Canvas (course management software) was not able to be used to give them real time data on their course grades. There was no way to use the Canvas grade reporting system with the exam retakes, so the students were asked to send an email for course grade updates.

In general, the specifications grading system made little difference to the students at the top of the class. They completed the homework and quizzes with high marks and passed the exams on their first try. They turned in high quality research and final projects, and received high grades in the course. One student did express some pride in earning all the tokens and never needing to use them. He planned to frame them because he did not need to turn them in during the semester, so maybe the system did add a little sense of accomplishment for the top students.

Where the new system did make a difference was with the students who struggled with the course material. Several students were able to pass the course who probably would not have passed with a traditional grading system because they were able to go back and learn the course material for the exam retakes. These students often came to office hours and asked for extra help after failing an exam the first time. The students who struggled did achieve a much better understanding of the course outcomes in the end. With a traditional grading system, these students probably would have been right at the border line for passing the course. However, with the specifications grading system, they were able to go back, get a better understanding of the course outcomes, and they were all able to pass the course.

As shown in the comparison with a class that used a standard grading system, many of the students in the middle range of abilities definitely benefited from the specifications grading system. Some of this type of student, at some point in the semester, had an especially busy week during a midterm exam, or had some external circumstance which kept them from preparing as much as they really needed to for an exam. Consequently, they did not fully understand one or two of the course outcomes. With a traditional grading system, they would have still passed the class with a fairly low course grade. With the exam retakes, they were able to go back and revisit a concept that they did not understand the first time and improve their understanding (and their course grade). It provided these students the opportunity and motivation to go back and learn something that they would have missed without the new grading system.

While some students perceived the eighty percent minimum exam score as too high, it really was an appropriate level for this course. In the end, all the students were able to achieve this mark on all the exams. A few students had as many as six exam retakes, and one student took the first exam four times, but they were all able to achieve the eighty percent required on all exams. There were two students who did not earn enough tokens for the retakes that they needed. However, when it became clear that these two students would not be able to earn

enough tokens, the instructor offered them the chance to pass the course with the lowest possible grade (2.0) if they earned an eighty percent on all the midterm exams ignoring the tokens. They both did. The authors of the original work that this system was based on had offered a similar path for their students.[7] There was another student who took each exam exactly twice. He would typically earn about sixty percent on each exam the first time. He would then go back, study the course material, and pass the exam with an eighty percent on the second attempt.

7. Summary and Conclusions

While there is definitely room for improvement with the token system and the final grading system, the specifications grading did perform as designed. Students were forced to go back and indeed master all of the course outcomes before receiving a passing grade in the course. In the end, all of the students did pass all of the exams and in turn passed the class. It definitely took more of the instructor's time to write, administer, and grade all of the exam retakes. However, in future semesters the time commitment for the instructor would be about the same as giving one additional midterm exam. There is no doubt that students, in general, did achieve a more thorough understanding of course learning outcomes using the specifications grading system.

The main apprehension about the specifications grading system lies in allowing multiple exam retakes. There is a question about the appropriateness of allowing a student to fail an exam three times before finally learning the course material. It seems a little unrealistic to expect that a future employer would allow an engineer to come up with three incorrect solutions before understanding how to formulate a problem correctly. On the other hand, an educational testing environment where students are forced to work alone is not a realistic engineering work environment either.

Finally, upon examination, the final course grades using the specifications grading were really too high. While the mechanics of the system did help improve student learning of all course outcomes, it also inflated the course grades by allowing students to retake exams and then get full credit for the exam portion of the course grade. Perhaps a better system would be to keep the requirement for each student to get an eighty percent on all exams to pass the class, but also include the lower exam grades in the calculation of their final course grade. In addition, it may not really be necessary for students to be able to substitute low homework and video quiz grades with tokens.

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