2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #38868

Ungraded Classrooms: A Pattern for Learning in Engineering Modeled after Expert Practitioners

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Abstract

Practitioners have knowledge bases in the subject matter that can be both deep and broad, while researchers often have knowledge bases that are very deep yet narrow. Interestingly, practitioners develop a deep and broad mastery of the subject matter most often during their practice rather than in the University setting that they were educated in. Most experts in academia will also readily concede that their mastery of the subject matter came not in a conventional classroom but in the daily struggle to study their subject in great detail, i.e., in the course of their practice. How can we help students learn in the University classroom setting like practitioners learn and develop both deep and broad knowledge bases? In our view students can best learn in much the same way that experts learn (as Marshall M. Lib strongly suggested in 1996 to ASEE). We propose that conscious implementation of ungraded classrooms is an ideal means to deepen engineering formation. This paper examines the impact of ungraded classrooms in geotechnical engineering classrooms at the junior and senior undergraduate levels. Throughout this time period student opinion surveys and student learning outcomes data have been collected to evaluate the effectiveness and reception of ungraded classrooms. These classrooms have a final grade, but the individual homework, quizzes, projects, and exams are treated as assignments in the engineering office. They are submitted, reviewed, and then revised. Revisions occur as many times as needed until mastery is demonstrated, or the semester ends. At the end of the semester, the final grade is determined by instructor and student in one-on-one conference, in which the student's overall learning and effort are evaluated holistically rather than an accumulation of points. This approach has help shift student attitudes away from "the grade is what matters" towards "it's the learning that matters." The ungraded approach has been well received by the students, while student final exam scores have significantly risen as a consequence of semester-long mastery of content rather than point accumulation.

Introduction

Before discussing the ungraded classroom, our findings on its effectiveness in our classrooms over a period of 5 years, and a discussion on how it may help other educators, it is worth introducing, at a fundamental level, why we decided to adopt the ungraded classroom in the first place. To do this, we ask a question: How does an expert academic or practitioner learn deeply and master their field? Marshall Lib asked this question to ASEE in 1996 [1]. While he used the analogy of learning to play a sport to how expert engineers form, and that often that formation is outside of the classroom and subsequent to the formal education of the person, we see significant opportunities to heighten engineering formation in the classroom through pedagogical techniques that follow the call of Marshall Lib. Again, how does an expert academic or practitioner learn deeply and master their field? Quite simply and intuitively.

Lib [1] described a series of steps used to develop high levels of skill in a sport. These steps included drills and practice, a coach, and most importantly by playing the sport. Lib contrasted these steps to a conventional engineering classroom approach wherein a person is being talked to about the sport and rarely, if ever, plays. In the context of the engineering classroom, formation of engineers, and development of subject mastery we summarize these simple steps proposed by Lib as: 1) a series of iterative tasks repeated many times until correct, 2) by working with experts who observe and instruct and correct and provide a structure of iterative and progressive constructive failure, and 3) by reflecting on their progress and growth. This perspective is fundamental to deep and lasting learning that persists after the final exam [2-4].

In this paper we show that ungraded classrooms have significant potential as a vehicle to enhance engineering education as it models the learning and development of experts. We do this through presentation of student response to ungraded classrooms in terms of both student opinions and in comparison, of graded instruments.

The Expert

Consider a practicing engineer, who is a subject matter expert of renown in industry and respected by academic peers. This person likely received a formal education at a respected institution of higher education. Leaving the university experience, the person was not an expert, but had a base of knowledge and skills that provide a foundation for the career. As a new graduate, this person could not perform many designs quickly and required the guidance of a senior engineer. In this thought experiment, the person is not asked immediately upon graduation to stamp engineering drawings or provide recommendations to clients alone. On the contrary, in the office, the person is placed in a diverse group of peers and experts. The person is tasked to perform a set of activities. The results are then reviewed by more senior and experienced engineers, who provide comment and instruction for revision and iteration. Revision and iteration are part of the engineering process [5]. The person revises the work until it is satisfactory for providing to the client as judged by the senior expert. The senior expert often asks the person to think critically about what they could have done better, where there were opportunities to improve the process, and how the organization could better support the work. This process repeats itself many times. Products are developed, iterated, revised, reflected upon, and delivered. After some years, the person is given more freedom to work with less supervision but continues this process on their own until they have mastered the subject and are now helping new graduates develop as engineers. They are now reviewing the work of others, guiding the revisions, and asking the questions that will help the new graduate to develop and grow as an engineer. For academic experts, this thought experiment of a practitioner subject matter expert should feel virtually identical to the process of graduate research, dissertation writing, post-doctoral scholarship, and the years leading up to tenure.

Within engineering instruction, the course design and pedagogical approaches can be successful for long-term deep learning and formation of engineers when the educator helps the students with both fluency (i.e., practice) and in doing engineering (i.e., working with an expert to receive feedback, revise, iterate, critically reviewing their work) to achieve deep learning under the guidance of an instructor who is the master of the content. Many pedagogical tools have been proposed to help the educator with this mission. Ranging from Active Learning [6-8], Productive Failure [9-11], Flipped Classrooms [12-14], Specifications Grading [15-17], Contract Grading [18-20], Mastery Grading [21-23], The 85% rule for optimal learning [24-26], to a litany of other tools and techniques, means and methods. When examining these pedagogical approaches, we find that individually, each has significant merit, yet can be added to for us as a profession to reach the ultimate potential that lays in engineering education. When combined with the ungraded classroom [27-32], we see a highly effective synergy that can replicate in the classroom the effective process of deep learning and engineering formation exhibited in both the engineering practitioner and academic expert. We find that, when combined with the active learning and productive failure in-class approaches already being used commonly across campuses, that ungraded classrooms are able to effectively replicate the expert formation process and enhance the learning of all students in the classroom.

The Ungraded Classroom

Like others [33], our impulse to go gradeless came from a shared belief that students should have a more active role in their learning and assessment. When we compared the deep learning observed in experts to the relatively shallow learning evidenced by students forgetting much of their A-level work over a quick winter break, we thought that there must be something that can be done to deepen learning beyond the end of the semester. We concluded that for deeper learning to occur, students must have a more active role in their learning and assessment. We note that an active role in learning is a far cry from "active learning" approaches used in classrooms [34]. Active Learning is something that the educator does, rather than the student themselves taking the active role in their learning.

Like many others [35], we hypothesized that grades and grading themselves may partially be to blame. It is well known that grades and conventional grading approaches have limitations. The wonderful summary by Ko [35], lists many of these limitations including: a source of systemic inequity, signaling to students whether they belong or not, putting the focus on grades rather than learning, exacerbating inequities for marginalized identity groups, etc. We observed that students have become quite expert in accumulating the points needed for the grade they desire at the expense of their learning and development as engineers. We observed students who desire a B, only doing the exact amount of work needed for the B and no more. Tragically leaving critical learning "on the table." Students who desired only a C, knowing that if only 70% of mastery is required for their goal, they would put forth only that effort. Obviously, this is not a summary or judgement of all students. These were observations that spurred our investigation into alternative grading philosophies that could ameliorate these conditions while providing the gains in engineering formation we desired in our students. In examination of grading philosophies such as Specifications Grading [15-17], Contract Grading [18-20], Mastery Grading [21-23], were found much merit, but did not find the holistic solution that married with the proposal of Marshall Lib [1]. In the writings of Susan Blum [27], we found a solution in the ungraded classroom.

The ungraded classroom has been described in detail in the literature for the Scholarship of Teaching and Learning [27-32] but has not received significant attention in science and engineering. Most of the work on ungraded classrooms has come from other fields of study in the liberal arts, law, and medicine [36]. As there may be much apprehension in engineering educators in the use of the term 'ungraded' an explanation of the approach is warranted.

Ko [35] explains the methodology: "*Ungrading, as the name suggests, completely breaks down the system of instructor bookkeeping and point/percentage calculation to determine a final grade for each student. Grades are not part of the routine of the course and the instructor instead focuses on other aspects of teaching: delivering content, coaching students, interacting with individuals or groups, answering questions, and providing feedback. Instead, students decide on their own grade usually in consultation with the instructor.…... The final agreed upon grade is then submitted to the registrar and legitimized. This system is the greatest departure from traditional grading schema and maximizes the power students wield in their undergraduate courses. Ungrading allows students to self-advocate for the grades they feel they deserve rather than allowing decision-making power only to be left to the instructor. Rather than trying to mitigate any negative consequences of grades on learning or create an "un-gameable" system for students, instructors opt out of any of the formalities of grading besides submitting the final grade. Instructors interested in furthering equity among their students may exercise veto power should the student-chosen grade be lower or higher than the instructor believes is merited. Students from marginalized identities may in fact undervalue themselves and their work due to internalized stereotypes and imposter syndrome, thus instructors who have seen the spectrum of student work can combat students' own biases. Releasing grades from the instructor's control may be daunting but eliminating much of grading's administrivia may also free instructors to focus more on the goals of their teaching. Student engagement during class time and on assignments should then be motivated by a desire to learn and inherent interest since students no longer feel constrained.… Along with this unrivaled opportunity for students to share power with the instructor and exercise their agency, students have a say in how merit should be defined in the college classroom. In determining and arguing for their grade, students will articulate what they have brought to the course, which may differ from the instructor's preconceived notions of merit.*"

There is still a grade in the ungraded classroom! The instructor must still assign a grade for the class. However, rather than point accumulation, the grade is based on the proportion of the material mastered in the semester. While several different schemas have been proposed in the literature, the common thread to grade assignment is as follows:

1. Assignments are reviewed by the instructor and teaching assistants rather than graded. Feedback is provided, and the students must revise and resubmit in order to receive credit for the assignment. Essentially, the assignment does not count until it is correct.
2. Mid-term exams are likewise reviewed, returned to the students for correction, and not counted until mastery has been demonstrated on all of the topics of the exam.
3. Late semester assignments are not revised but are reviewed and feedback provided to help the student prepare for the final exam.
4. Mid-term and end-of-term self-reflections are written by the student examining their own learning, progress, and achievements.
5. The final grade is determined by the student and instructor in a short end-of semester conference that reviews all of the materials that the student has submitted and revised, the final exam, as well as the written self-reflections by the student.

What makes the ungraded classroom so potentially effective for engineering education? The fact that it centralizes revisions performed under the watchful eye of the instructor. It is in the revisions… the fixing the mistakes and learning from those mistakes, that deep learning occurs [37]. It is in the fixing of errors and mistakes that the model expert practitioner iteratively develops mastery. By allowing students to make some mistakes, but then strongly encouraging them to re-assess and fix those mistakes, innovate to find solutions, rather than fearfully memorizing or exact copying that we are able to answer the call of Lib [38].

Methodology

Since the fall of 2019, we have been using ungraded approaches in the geotechnical engineering undergraduate classroom. This has included two junior level soil mechanics classes and two senior lever geotechnical design electives. The introductory soil mechanics course (GEO I) has 60 to 80 students in each instance it is taught, while GEO II has 30 to 50 students in each instance it is taught. The two senior design electives have 12 to 30 students in each section. All four courses are completed over a 16-week semester that is decomposed into 4 modules of instruction over 12 weeks. Exams, holidays, and finals consume the rest of the semester. Students are evaluated with rich and substantive feedback for each submission, but no numerical grade is included for any submission. Except for late-semester submittals, all submissions are required to be revised in order to be counted to the student's credit. The majority of students are enrolled in at least 2 of the 4 courses, and this overlap is noted.

As per the ungraded methodology listed previously, the final grade is determined in conference between student and instructor. The key instruments for the conference are the student's mid-term and final self-assessments, and the final exam. Students are asked to assign themselves a grade supported by evidence. The evidence is the list of assignments submitted, revised, and completed, instructor feedback, examples of growth and improvement over the semester, and their own sense of mastery of the material. The mid-term and final self-reflections are structured written documents formulated after examples from the literature on ungraded classrooms. Key to the self-reflections are the following questions:

1. How much of the assigned work have you completed and revised per instructor feedback?
2. How much of the material of the course do you feel that you have mastered?
3. What could you have done better this semester to learn better?
4. What did you do well this semester that enabled your learning?
5. If you had to give yourself a grade for the course (based on your learning), what would it be?

The course structure for the junior level classes is shown in Table 1, while the course structure of the senior level electives is shown in Table 2. Key differences between the junior and senior level courses are that the senior level courses have less assigned homework and a semester-long term project. This semester-long term project includes two interim deliverables that are reviewed by the instructor and revised by the students into a final deliverable. These projects are group projects that are a nearly complete design of an engineered system such as the foundations for a large, big box store, using the actual site information for a real-world project, the actual structural loads from the actual building, and the constraints of the site known at the time of design.

Table 1. Structure of junior level geotechnical courses

Course Structure	Modules 1 and 2						Mid-Term	Modules 3 and 4						Final
Week / Topic	1	2	3	4	5	6	Exam	7	8	9	10	11	12	Exam
Quiz Due	1	2	3	4	5	6		7	8	9	10	11	12	
Quiz Revisions Due		1	2	3	4	5		6	7	8	9	10		
HW Due	1	2	3	4	5	6		7	8	9	10	11	12	
HW Revisions Due			1	2	3	4		5	6	7	8	9	10	
Other Due Dates					Self-Assessment				Exam Revisions				Self-Assessment	

Note: Quiz 11 and 12, HW 11 and 12, and Final Exam are not revised due to time limitations for the semester.

Table 2. Structure of senior level geotechnical design electives.

Course Structure	Modules 1 and 2						Mid-Term	Modules 3 and 4						Final
Week / Topic	1	2	3	4	5	6	Exam	7	8	9	10	11	12	Exam
Quiz Due	1	2	3	4	5	6		7	8	9	10	11	12	
Quiz Revisions Due		1	2	3	4	5		6	7	8	9	10		
HW Due		1		2		3		4		5		6		
HW Revisions Due				1		2		3		4		5		
Semester Project Due				Deliverable 1					Deliverable 1 Rev + 2				2 Rev + 3	
Other Due Dates					Self-Assessment				Exam Revisions				Self-Assessment	

Note: Quiz 11 and 12, HW 6, Final Project Deliverable and Final Exam are not revised due to time limitations for the semester.

Independent of the student's own reflection, the instructor selects a grade for the student before the conference, based on their observations of learning and growth and records of completed work. Thus, the instructor and student both bring evidence to the conference to determine the final grade. The proposed grades are compared, and a brief discussion ensues in which the final grade is determined between the two parties. The conference is usually brief, less than 10 minutes. In most cases the conference is as quick as 5-minutes, as both parties generally have a good sense of student success. Some may feel that 5-minutes may not be sufficient time for discussion of a final grade without trying the method. However, admittedly limited experience is strong; that both student and instructor, when armed with the evidence of a semester before them, can come to consensus on the earned grade for the semester. We do not find excessive (or any instances) of arguments or appeals. This fear of arguments and appeals has been proposed by those who have not tried ungraded classrooms in nearly every instance it is discussed. However, we have not encountered such litigiousness in students.

The instructor also collects feedback from students via class surveys. Student feedback on the ungraded approach from instructor administered blind surveys (using the campus learning management system that enables student confidentiality) and end of term campus administered class evaluations were compiled and tabulated. The grades, exam results, and student feedback were then aggregated and compared to the same aggregated data from semesters prior to implementation of the ungraded classroom in the same courses in the years from 2015 through spring of 2019.

For reference on the approach to exam rigor and exam writing, all exams were devised and conceived under the assumptions of the “85% rule for optimal learning” concept [24-26]. This concept comes from the neuroscience literature that follows learning studies that have shown that optimal learning occurs when the average person in a cohort is being challenged at the edge of their competence – not so hard that they are discouraged, but not so easy that they get bored. This concept has been applied widely to machine learning and computer science [39-40]. Exams are written so that the target is for an average student to complete 85% of the exam correctly.

Results

Exam scores at mid-term and final can be compared across cohorts and courses. As exams must change with time, in this study we compare only a subset of topics, items and problems of the larger exam that are held as similar as possible over time. Minor changes are needed in each new section due to changes in textbook, state of knowledge, and to prevent cheating with old exams. However, the set of items identified in 2015 as core “study items” has been held as constant as possible to allow comparisons over time and across cohorts. Table 3 presents the raw exam score means and standard deviations for GEO I. Figure 1 presents the midterm and final exam changes with implementation of the ungraded approach for the study items only. All results in Table 3 and Figure 1 are out of a maximum of 100. Note that in the ungraded sections, the students were required to correct and return their midterm exams, which may play a role in decreased midterm scores pre-revisions presented in Table 3 and Figure 1. However, all students in the ungraded cohorts were required to submit a 100% midterm revision in order to pass the class. Thus, mastery of all items on the midterm was encouraged rather than allowing students to pass critical learning items by in the passage of the semester.

Table 3. Raw exam scores showing mean (standard deviation) in GEO I

		Study Items		Non-Study Items	
Condition	**N**	**Midterm**	**Final**	**Midterm**	**Final**
Graded	232	78.40 (12.04)	75.94 (15.49)	79.12 (11.09)	77.28 (9.65)
Ungraded	336	74.08 (19.06)	88.67 (14.79)	74.28 (16.22)	89.16 (13.36)

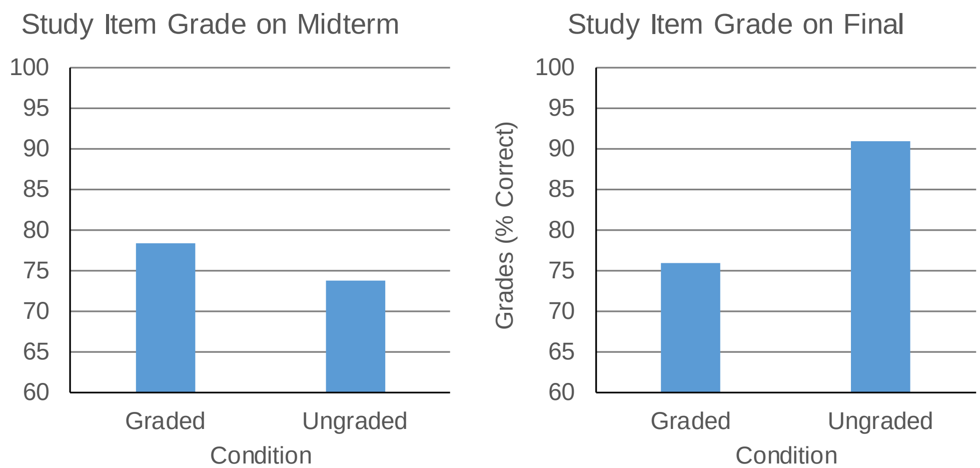

Figure 1. Summary of study item grades on mid-term and final exams in graded and ungraded sections of GEO I.

We initially see in GEO I that the ungraded mid-terms are lower in score than the graded sections on the study items. However, the ungraded final exams scored much higher than the graded final exams. We see similar trends in the three other courses.

Next, we evaluated the trends in Figure 1 on student ability. We used the midterm scores as a proxy of student ability (pre-revisions). We split our student sample into three parts by ability, with the “low” being students who scored in the bottom 33% on the midterm, and “high” being those that scored in the top 33% on the midterm. We then reanalyzed the GEO I data by this ternary split of ability. The goal of this proxy separation by ability is to evaluate if the ungraded approach is having a positive effect on students conventionally considered as low ability by conventional grading metrics. Our hypothesis was that the low ability students would be more positively impacted by the ungraded approach than high ability students. We posed this as we felt that high ability students would be successful in most pedagogical paradigms, but that those that we most need to affect and enable learning in are those that many conventional techniques would leave behind. Table 4 and Figure 2 present this ternary split of ability and impact on mid-term and final grades.

Table 4. Ungraded increase on final exam by ternary split of ability

			Graded		Ungraded		Ungraded Increase	
Ability	N_{graded}	$N_{ungraded}$	**Midterm**	**Final Exam**	**Midterm**	**Final Exam**	**Midterm**	**Final Exam**
Low	77	112	67.23	60.28	60.73	83.55	-6.5	23.27
Med	78	112	78.01	75.39	70.02	85.21	-7.99	9.82
High	77	112	89.96	92.14	91.48	97.26	1.52	5.12

The ungraded sections showed strongly that the high ability student midterm exams were consistent with graded sections. However, the midterm for lower ability students scored less. We attribute this to the students knowing that they will be making revisions and putting less effort into the midterm exams. The flip side is the final exams, in which the ungraded lower ability students scored much higher than in the graded sections. This result help true over the other three courses in the study. We attribute this difference in final exam scores by lower ability students to the constant revisions being performed all semester, strongly encouraging the students to learn from mistakes all along the semester. Did some students still fail? Yes. Although the standard deviations on the exams were 15 to 20%, there are still some students that receive D and F on the exams and thus in the courses overall.

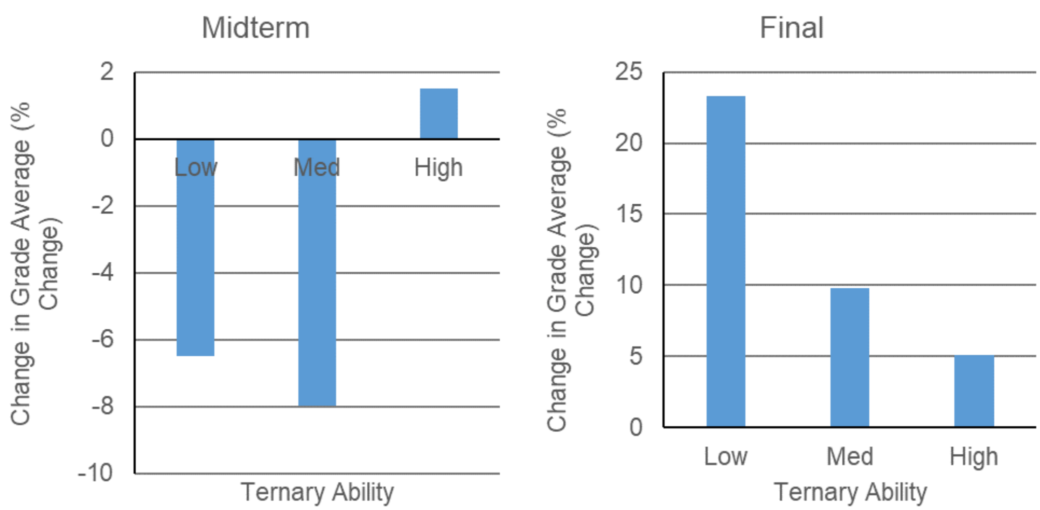

Figure 2. Ungraded increase on final exam by ternary split of ability

Meanwhile, as the final grade is decided by both instructor and student in conference, there is genuine concern in the engineering education community that students will consistently and perhaps aggressively over-estimate their grade and demand a grade higher than the expert (i.e., the instructor) would award based on the cumulative effort, achievement, and learning. In order to study this, the student versus instructor initial grade estimates were compared and sorted by the number of times a student has been in an ungraded section. Figures 3 and 4 present the compilation by both percentage of the cohort grades and by raw number of instances. In Figures 3 and 4, positive numbers are where the student has over-estimated their grade relative to the instructor, while negative numbers are where the student has under-estimated their grade relative to the instructor. We have sorted these by ½ of a grade to account of plus and minus grades. At our institution the final grade in the system do not allow for degrees on letter grades, but students were asked to provide a degree on the letter grade in terms of a plus or minus if they desired (and most did). Figure 3 presents the percentages of grades in a semester, while Figure 4 presents the actual number of instances. Figure 3 then is normalized and Figure 4 is non-normalized.

We find that students are more likely to under-estimate their learning than over-estimate! We also find that as the students are exposed to more and more ungraded sections that their estimates fall in line more closely with the instructor. There are outlier students, but in only a very few cases has a student declared themselves an A when C work and learning was evidenced at the conference. Indeed, we find that many students are harder on themselves than an instructor.

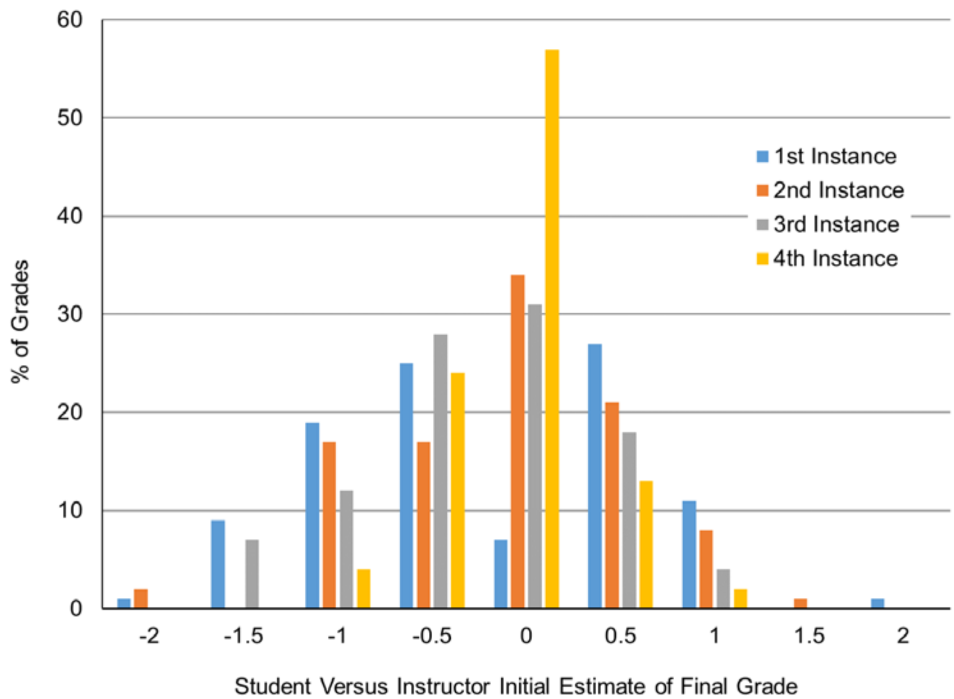

Figure 3. Proportion of entire study sample in which student and instructor initial estimate of final grade agreed or differed sorted by number of times a student has been in an ungraded section. Negative indicates the student is proposing a lower grade than the instruction. Positive indicates the student is proposing a higher grade.

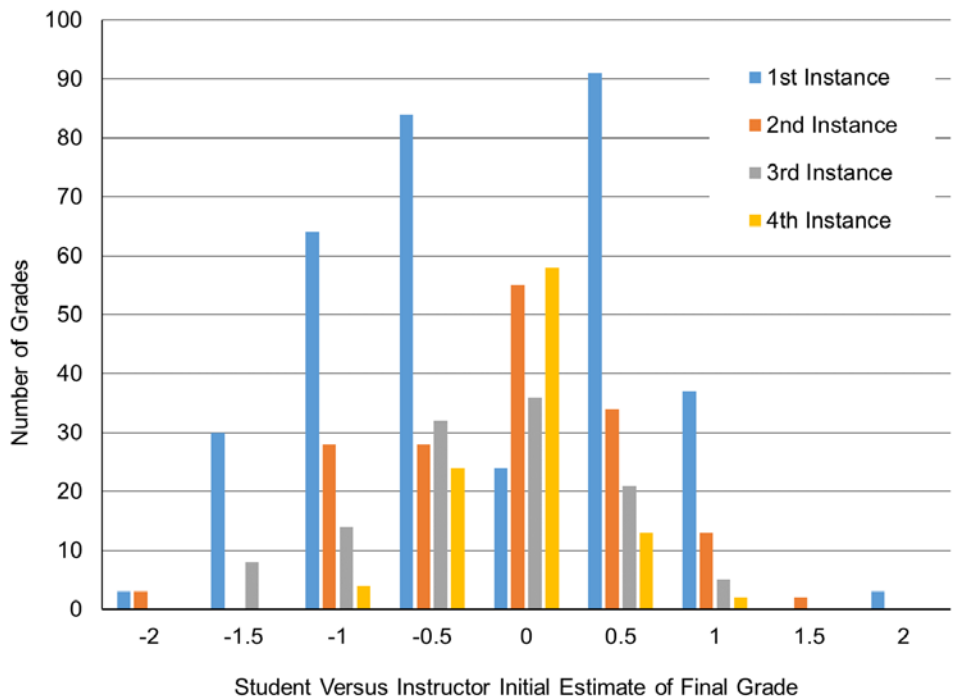

Figure 4. Instances of agreement between student estimated final grade and instructor estimated final grade; sorted by number of times a student has been in an ungraded section. Negative indicates the student is proposing a lower grade than the instruction. Positive indicates the student is proposing a higher grade.

Lastly, student feedback on the ungraded classroom is tabulated and considered. Since the ungraded approach began in 2019, prior to the COVID-19 SARS-2 pandemic, we felt it fitting to compare pre-pandemic student response to post-pandemic student response. Figure 5 shows the compilation of several years' worth (2019-2022) of 5-point Likert Scale Surveys on ungraded classrooms. The 5-point scale has two points on favorable, two points on unfavorable, and a neutral option. In Figure 5, both the moderately and strongly favorable data is combined across the pre- and post-pandemic timelines. We include Spring of 2020 in the pre-pandemic paradigm and Fall of 2020 in post-pandemic. The ungraded approach is generally well received by students, echoing findings by others [33], and has held consistent during and since the pandemic.

Students generally praise the ability to revise their work in end of semester course evaluations. Some express some apprehension of their grades when accustomed to being able to tally points all semester long. Some of these students are less apprehensive in their second exposure. Those semesters in which review results are delayed back to students engender more angst than in semesters in which review results are delivered more promptly. Other students have expressed gratitude for being liberated from compiling points as the focus of the semester. The student favorability does increase mid-term to final, showing that the more students are exposed to alternative grading approaches, their apprehension fades.

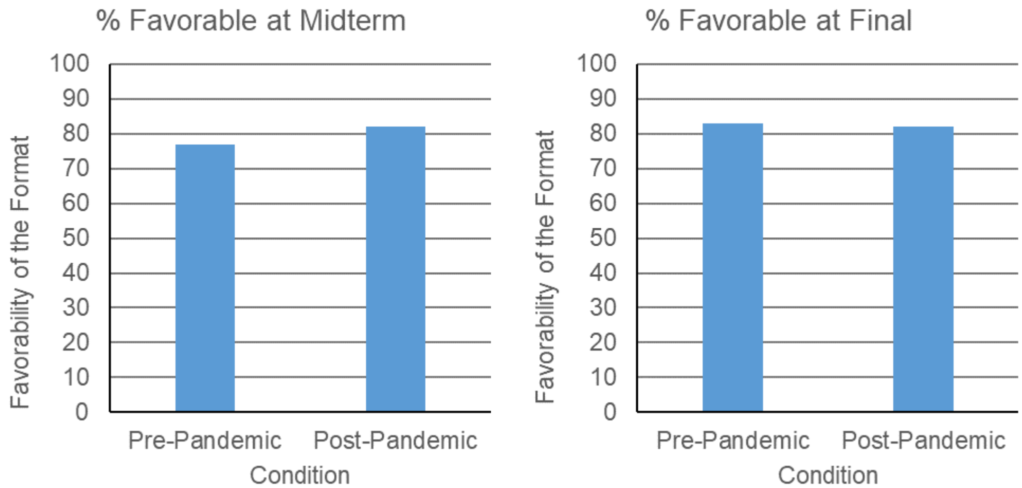

Figure 5. Student acceptance of the ungraded classroom approach over the pre- and post-COVID-19 pandemic time scales.

Discussion

We find that the biggest benefit of the ungraded classroom is to students who are perennial C students in other courses, wherein they have one shot to perform well on each assignment or exam. Whether it be anxiety on the pressure to perform, or the need for a bit more time, we find that these students can do quite well in an ungraded classroom. For students from marginalized identify groups, differing cognitive abilities, differing physical abilities, differing home or domestic situations, and non-traditional students we find some of the most enthusiastic acceptance of the ungraded classroom. Non-traditional students are in particular effusive about the approach. Many non-traditional students are raising families, returning from years of work experience, veterans, and working professionals. For these students, they have started to see the importance of revisions and feedback as essential pieces of learning and development through their life experiences. Many of these students, whether non-traditional, or perennial C students, have enormous capacity as engineers and wonderful potential, but may be held back by conventional grading schema that harshly penalizes mistakes and allows no path to learn from those mistakes.

We find most resistance to the ungraded classroom to traditional students who want a B, and to do little more than do the work needed to get a B. These students have been served well by grading schemas that reward point accumulation, copying, and “cramming” before an exam. In many cases, they have been highly honed by the educational system to think of only the final grade and little about semester-to-semester carryover of knowledge or making deep mental connections that will benefit future careers. One benefit of the end of semester conference with students is that we have a chance to explore why they embraced the format or why not.

As we look at student outcomes, some outcomes are difficult to measure. We do not have measurements of semester-to-semester retention of material from GEO I to GEO II and GEO II to senior design electives, but we have seen marginally to significantly better semester to semester retention in this subject matter in individuals and cohorts. This semester-to-semester retention is a sign that deeper mental connections are being made. We attribute this observation to the concept that has been posed in the past: “people learn more from their mistakes.” While we are not aware of any neuroscience basis for this statement, it is observationally making sense to what we see.

Most helpful tool to help students keep in track in the semester are the weekly quizzes, that have hard deadlines for both initial submittal and revisions. These quizzes are not overlong and are low stakes. We find that frequent, low-stakes, opportunities for students to receive feedback and check their learning to be an essential part of the success we have seen in increasing final exam results semester to semester. The quizzes are ungraded, like all other submittals. The difference between quizzes and other assignments are the hard deadlines, to incentivize timeline learning.

In terms of limitations and confounding factors to this paper, we were still using active learning and other pedagogical tools and techniques in the classroom. Those have not been removed. Thus, the drift in grades since implementing the ungraded approach may partially be a benefit of the evolution of our in-class techniques. We also note that instructional skill level has increased with time, and that instructional skill pre-2019 was not as honed as since implementation of the ungraded classrooms since 2019. Other instructors have taught these classes in other sections in the period of 2015-2022. We have not compared any data with their courses, as no rigorous controls were implemented to allow for comparison with courses from other instructors.

A key benefit to faculty from the ungraded approach has been the overall reduction in time spent reviewing and correcting student work. This may seem counter intuitive. The initial inclination of faculty when hearing the ungraded classroom process is to assume that it means MORE time spent reviewing and correcting student work. Faculty rightly assume from previous experience that they will spend more time than normal reviewing student work. However, we find it takes less time. Our assumption as to why there is less time being spent on reviewing and correcting student work is that we see students as more likely to do their homework correct the first time if they will be asked to make corrections and resubmit. A mostly correct submittal is quicker to review than one fraught with errors and omissions. The student desire to do less work works to faculty advantage here, in superior initial submissions. This held true at both mid-term and final across the semester(s).

The process has not been without its struggles. After several years and multiple courses, consistent issues have emerged. Key among these issues is uniform and class-wide homework submittals in a timely manner, and then in getting the homework revisions in in a timely manner.

Initial iterations of the ungraded approach had no deadlines for homework, a recommendation from the non-engineering education research literature. However, this did not go well for us. We moved to soft deadlines, with improved student homework submittal consistency. The soft deadlines were still not as effective as desired. Thus, since 2021, we have had to implement hard deadlines for initial homework submittals and a requirement that 80% of homework be submitted and revised in order to pass the class. Some students have benefited from multiple conferences with the instructor, and interim conferences are welcome rather than mandating only a single end of semester conference. Many students do not feel a need to meet more than the end of the semester, while other students enjoy more frequent conferences, held at office hours. This becomes a unique means to entice students to office hours.

Conclusion

Ungrading and ungraded classrooms remain a developing area of pedagogical research in the engineering education community. However, their potential to help students develop deeper learning and accelerate the formation of engineers is an exciting step forward, especially when coupled with other well-validated pedagogical tools. Educators who are interested in ungrading have proven techniques to rely on in their implementation, while flexibility to adjust the methods to the specifics of their course, topic, and field of study. Since 2019, we have found that our emphasis on feedback and revisions has given students more opportunity to learn if they respond in a timely manner. For some students, this has helped shift the focus from grades to learning. Other students have not taken advantage of the opportunity fully yet have still benefited as observed in increased final exam scores. Key to the ungraded approach has been end of semester conferences with students that have helped them metacognitively consider their own thinking and learning. As we search for enhanced means to answer the call of Marshal Lib and push forward engineering education, we find ungrading a potentially indispensable tool to accompany the many pedagogical tools available in the engineering educator's toolbox.

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