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Grading for Enhanced Motivation and Learning

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Grading for enhanced motivation and learning

One student commented, "[The grading method] makes sure the student has full mastery of the course material before they are awarded the units," another said, "Somehow I actually learned something but wasn't super stressed all quarter", and finally, "Having our grade in our own hands, for once, is refreshing." The students are referring to a grading method known as "mastery" grading. Mastery grading is a combination of defining and assessing the competencies needed and creating an opportunity for learning beyond the competencies. Instead of having students do all the work and receiving a portion of the points on each assignment with the grade being a weighted average of all the assignments, the paradigm is shifted. In this mastery grading method, students are asked to demonstrate a high level of mastery on the most important concepts in the course, a subset of the learning objectives. This demonstrated mastery usually occurs through the traditional midterm and final. The difference is that students must score at a 90% level on these tests to pass the class. This can be achieved through multiple test retake attempts. This level of mastery earns the students a "C". In order to earn a higher grade, a student must demonstrate learning beyond the mastery level. This might include a research report or project, or it might be an additional test of more advanced topics. Mastery grading draws from concepts in "Self-Determination Theory" of motivation. Students have autonomy in their own level of learning and feel much more in control of their grade. In addition, students are motivated to prove mastery of the topics. The grading method also seems to relieve some of the stress that the typical engineering student feels.

This work-in-progress paper begins with a discussion of the theoretical foundation of the method. We describe the particular implementation of this approach in several engineering courses at California Polytechnic State University, San Luis Obispo, and present results of both qualitative and quantitative assessments of the impact.

Introduction

As we began to look at the traditional process of grading and the assumptions on which the process is based, it became clear that this practice is an unexamined product of the system of education that began long ago. As far back as the medieval times, the "teacher" was the expert and the student was acquiring knowledge from this expert[1]. For centuries, the teacher evaluated the quality of acquisition and assigned a "grade." As we enter the 21st century this "expert" model of education has come into question, especially with adult learners in higher education. Alison King's often quoted article *From Sage on the Stage to Guide on the Side*[2] highlighted this concept. The university faculty is no longer the only authority on topics as information is widely available. This shift is changing many aspects of education: structures for learning such as open education resources (OER) and MOOCs, practices and pedagogies like inquiry based or project based learning, and credentialing methods like badging system. Although there has been some progress in restructuring the grading systems especially in K12[3-6], grading in higher education has remained essentially unchanged. The current system is still based on an authorized expert evaluating a learner's progress on a predetermined path. In this system, there is little room for self-directed, creative, or innovative learning.

Beyond the traditional expert model, the use of a points system is also unexamined. In higher education, the assumed structure includes graded assignments and examinations with point values. The method we use is probably based on our own experience of being graded. We did well in this systems and thus think it is perfectly fit for the tasks of evaluation. Most of us habitually use this system, or tradition, without really looking at the alternatives. There are variations in use, but almost all are a minor adjustment to the points system[7,8]. Examples include a teacher offering extra credit for enrichment activities, or lower point values for late work. A more recent improvement creates learning objectives and rubrics so the student has a better understanding of the expectations[9]. Good rubrics also serve to give feedback for enhanced learning. However, a complete reevaluation of the current points system is long overdue.

There are unintended and undesirable consequences of the points-based system of grading. Much has been written about the negative impact of "curving" or norm-based grading[10], which includes decreased motivation, increased probability of cheating, and a disproportionately negative affect on women and minorities[11]. However, even if we move to more criterion-based, or points based, grading there are still many problems[12]. For instance, faculty use what Cross and Frary[13] called "hodgepodge grading" where grades are based not only on content but on effort and attitude[14]. This is prevalent in K12 education, but is also seen in higher education. In addition to grading on activities beyond content, there is the subjective nature of grading itself[15-17]. We act as if the grades are a "true" indication of achievement when even ABET discourages using grades for regulating the attainment of program outcomes[18]. Another unexamined consequence is that the instructor is set up as both a coach and a judge. This mixing of roles makes both ineffective[19]. The usefulness of an instructor as a coach is clear. We relish the opportunity to coach young people, to help them learn from our successes and failures. The process of communicating knowledge is pleasant for both parties, but when this process becomes one of judgment it is problematic. There is no longer freedom of inquiry as the inquiry itself becomes a mode of judging understanding. This then leads to students badgering about grades assigned and negotiations about the work done. Lastly, the application of detailed predetermined points structure decreases variability but leaves no room for creativity and innovation. The instructor decides what should be learned based on their own paradigm of what a good engineer should know, but this does not take into account the interests of the student or the ever-changing needs of the world. The underlying assumption of this predominant system is that human beings are not natural learners and must be forced to learn through external behavioral motivations such as reward and punishment.

A look through the literature shows that in the 1990's, before No Child Left Behind (NCLB), there was much talk about grading and assessment, mostly related to standards-based grading. The discussion faded from view as the consequences of NCLB focused on the detrimental effects of standardized testing. During these early discussions, educators developed other assessment methods like "contract grading"[20] or "menu system"[21]. More recently some educators have developed frameworks such as competency grading or specification grading[9] that uses a non-points system[22]. Although there isn't a definitive definition for the types of grading, in this paper the term "mastery grading" refers the method discussed in Lalley and Gentile[23]. Mastery grading can be thought of as a combination of requiring mastery of the most important competencies, and also creating an opportunity for learning beyond the basics.

The mastery grading described below is based on Self Determination Theory (SDT)[24]. SDT has been used in the educational setting for many years[25]. This theory identifies three social-contextual factors that enhance intrinsic motivation: Competency, Relatedness, and Autonomy. In addition, many who practice the application of SDT[26] point to the need for task relevance or meaning to enhance learning. These psychological states interact with one another; they affect and are affected by the learning environment to produce the overall learning result[27]. From this we have identified three aspects to describe mastery grading: Mastery of concepts (competency), Meaning or purpose for tasks (relevance), and Autonomy in learning.

Although some may argue that the system of higher education has all of these SDT characteristics, it is often difficult for students to see these when they are in a siloed classroom learning concepts that seem disconnected from each other or the world. If students were encouraged to see their choices in attending college, they might be able to see their own autonomy of choice in the classroom, but it is often opaque to them as they try to maneuver the demands of graded daily homework or project progress reports. Students could also see the progression of their mastery of concepts if they could reflect on what they didn't know three months ago or a year ago, but when they get a poor exam score they are more apt to feel discouraged. It is not to say that there haven't been attempts to enhance intrinsic motivation with great success. Particularly pedagogies that allow students to contextualize learning have been successful. This includes project based learning, service learning, and active learning[28-30]. These practices have helped to connect the purpose or meaning of the content learning to future careers or doing good in the world.

Mastery grading described

We are presenting here a method of grading that not only allows for reexamination of the current practice but is also based on theories that enhance intrinsic motivation. The elements that make up this grading method are explained using the Mastery, Meaning, and Autonomy categories.

We have used this method of grading since the Spring of 2013 at California Polytechnic State University, San Luis Obispo (Cal Poly) in Industrial Engineering, Materials Engineering, and Physics courses. Cal Poly is a non-PhD granting state university. The university is located in a small town in California. The college of engineering is fairly large (almost 6000 students, 95% undergraduates), has selective admissions (44,000 applicants for 4600 spots in 2014), and has high job placement of graduate. This grading method has been used in 11 different courses with over 700 students (see Table 1). Theses courses are mostly delivered using a flipped classroom where the lectures are available on video before class, and class time is used for activities and group work to deepen understanding. The learning management system (Moodle - Polylearn) is used extensively to support the students with resources for their independent learning. In addition, during the Fall of 2015, one course was taught at California State University, Los Angeles (Cal State LA), a state university that is less selective, where the students are less prepared academically, are more ethnically diverse, and have demands of work and home to attend to as commuter students. These 35 students at Cal State LA were as receptive to the method as the Cal Poly students.

Table 1: Course taught using Mastery Grading

Course at Cal Poly, SLO (unless indicated)	**Class level**	**Approximate Class size**
IME 239 – Cost Estimating and Control	Sophomore	50
IME 443- Facilities Planning	Senior	40
IME 544 –Advanced Engineering Economy	Graduate	25
IME 270 - Project Management	Freshman	10
IME 430 - Quality Engineering	Senior	60
IME 314 - Engineering Economy	Junior	50
ENGR 300 - Engineering Economy (Cal State LA)	Junior	35
PHYS 121 - College Physics	Freshman	20
MATE 325, 326, 327 – Transport Phenomena I, II, III	Junior	35
MATE 210 – Introduction to Materials Engineering	Sophomore	100
MATE 340 – Electronic Material Systems	Junior	40

The implementation of this method is slightly different in each course. The explanation below pertains to the Industrial Engineering courses.

Mastery. In order to pass the class with a "C," the student must prove mastery on a subset of most important learning objectives (LO). These LO include the main concepts in the class or the concepts most needed in subsequence courses. In order to prove mastery, the student has to score 90% correct on two midterms. The tested topics are usually quantitative in nature and the 90% threshold ensures mistakes are only at the level of arithmetic. The student may retake the midterm as many times as needed. Each midterm retake is different, but the concepts are the same. It usually takes three to four retakes for all the students to pass at the 90% level. The retakes are not given during class time, but are given in the evening (usually from 7:00 to 10:00PM). The midterms solutions are available on the Moodle system for students to review.

This mastery method encourages students to learn the material at a deep level. The theory is that although forgetting will most certainly occur, it is easier to relearn something when you have mastered it to begin with[31]. This also allows students to feel the accomplishment of learning something and getting good grades. It teaches skills of perseverance and success. In a traditional grading system, the teacher defines a moment in time when a student should learn the material then tests the student to see how much has been learned. In mastery grading, the learning is not in a predetermined time period but on the content level. The student learns content at a mastery level, however long that takes[23].

One of the most satisfying aspects of this method for the instructor is that students develop an interest in mastery. When tests are returned and the student has not passed (at 90%), they immediately attend to the test, trying to figure out where they went wrong. They compare work with their classmates knowing they need to learn the topic for the next retake.

Meaning. In order to achieve a higher grade, the student demonstrates mastery beyond the basics necessary to understand the topics. This could be demonstrated with another exam of more

advanced topics, or in the case of our classes, students apply concepts to a project or a research report. We call this "extension learning." Students can tap into their passions and seek to understand something of interest to them. If they want a "B" they do one "extension learning" if they want an "A" they do two. This increases the relevance of the material.

We also give students several options for predefined projects so that they can understand the expectations. There are students who have a very difficult time with the freedom and, therefore, appreciated a more typical predefined project. The large majority of students work on a project of their interest. Table 2 has an example list of reports done in some of the courses.

Table 2: project examples:

Course	**Project Description**
Quality Engineering	The application of electronic signatures for FDA validation at a biomedical firm where the student works
Quality Engineering	A quality plan for a local micro-brewery which includes metrics and statistical analysis of the brewing process
Quality Engineering	A research report on how quality is measured in financial investing
Cost Estimating and Controls	Personal budget tool for tracking and analysis in excel
Cost Estimating and Controls	Building and costing out a 3D printer. Then using the printer to make small plastic parts for resale. The profitability of this endeavor is fully analyzed.
Engineering Economy	Analysis of a mock investment in the stock market
Engineering Economy	A research report on Bitcoins as currency
Engineering Economy	Research the economics of NCAA college sports
Facilities design	Redesign of an assembly line for a local company with lean manufacturing in mind using simulation to validate

The projects are graded on a pass/fail basis. There aren't any prescribed expectations in the self-defined reports. Students are encouraged to turn in projects early so that we can give them feedback. Every time we've returned a report asking for more analysis the student agrees that the suggestions will help the final product. This method encourages students to push themselves to learn something new. One of the pleasant surprises of this method is that we get to know the students in a way we never did before. They share their passions and we learn. We are never bored reading the reports as they are on interesting, personal, and relevant subjects.

Autonomy: This method supports several different aspects of autonomy. First, the students can decide how much work they want to put into the class. We are accepting if a student desires to get a "C", which means that they don't do a project. Because the student feels they have control over their grade, very rarely do students complain about a final grade with this method.

Another aspect of autonomy is that there are no strict due dates. We do indicate that they might have to accommodate our schedule and workload if they desire feedback, but they can manage the workload on their own. Also, if a student is not ready for the midterm and would like to skip

the test, they are welcome to take the retake. This gives them the ability to manage their time for other classes and life demands.

The choice of a project topic is another aspect of autonomy. The students can choose a topic of interest and theoretically have more energy to learn.

Lastly, students are not required to attend class or to watch videos at any particular time. It is clear to them what needs to be done and they have the resources to accomplish the goals. All these changes allow us to be more of a coach and less of a policeman. We encourage and suggest, but do not demand. This has made the classroom much more pleasant for us and for the students.

This grading method makes sense when considering the cognitive aspects of learning. Lalley and Gentile[23] argue in the process of acquisition of knowledge that after a time forgetting is almost complete, but relearning is easier when the initial learning is at a deep level. In addition, Bloom[32] felt that a large majority of the students are perfectly able to obtain mastery. He argues that the rate of learning is quite variable, but the potential to learn is present in every person. Bloom also points to the importance of the teacher believing in the student's ability. Lalley and Gentile's and Bloom's orientation that forgetting is natural and most all students can achieve mastery was used to construct this grading system and learning environment where both deep learning and forgetting is accepted for all students.

Words of caution: There are several issues that are somewhat unrelated to grading, but have surfaced when we implemented this method. First, it is very helpful to use a flipped classroom pedagogy and a robust online learning management system like BlackBoard or Moodle. These techniques help the students manage their own acquisition of content and when studying for test retakes they have all the information they need. In addition, and probably more importantly, this method should not be tried unless you are willing to reexamine who you are in the classroom[33]. We are constantly confronted with students who tells us, with all honesty, that their other courses are more important to them and so they will only be doing the minimum amount of work in our class. We have had much practice in managing our ego and we now just wish them luck. We have a deep respect for students as people who are attempting to manage a life full of demands and expectations. We respect their choices just as we expect them to respect ours. We genuinely care about their learning and desire them to be creative thinkers and life-long learners. We believe this grading method supports them in this quest. If this orientation is not natural to you, then this method of grading may be difficult. The last issue is that changing the grading method in a course may stimulate department or institutional reactions. We are full professors and somewhat immune from pressure about grade distributions and grade inflation. McClam and Sevier[34] have an interesting cautionary tale about the disruption a simple change in grading had on an institution.

Methods

As this is a work-in-progress paper, the evaluation methods are also developing. We have used several different approaches of evaluation to attempt to both understand and validate the grading method. As a minimum, we hope that the grading method is no worse for students than the

traditional method, but we would like to ultimately measure the impact this method has on motivation, content learning, and life-long learning. To gain insight into possible ways to evaluating the efficacy, several surveys were administered: The Course Valuing Inventory (CVI)[35], the Situational Intrinsic Motivation scale (SIMS)[36], and several other items asking about the grading methods. And lastly, open-ended comments from student reflections were analyzed to attempt to understand the effect of the grading method. Table 3 below lists courses and evaluation methods used.

Table 3: Evaluation methods

Course	**Evaluation method**
IME 239 – Cost Estimating and Control	CVI, Open ended-comments
IME 314 Engineering Economy	CVI, SIMS, Misc Questions
ENGR 300 Engineering Economy	CVI, SIMS, Misc Questions

Course Valuing Inventory: Nehari and Bender[35] developed a survey that measures the self-reported value of a course in four dimensions: Course Value, Content Learning, Behavior Learning, and Personal Learning. We used this survey because of the relationship between value and engagement. Course Value asks the students to report on the overall value of the course and to indicate if they would recommend the course to others. Content Learning asks about the subject learning; if they understand it and can apply it. Behavioral Learning reflects aspects such as communication skills or goal setting. Personal Learning attempts to measure interpersonal qualities such as tolerance of others and reflection on feelings. The survey was administered in three sections (IME 239 in the spring of 2013, IME 314 in the Spring of 2015 and ENGR 300 in the Fall of 2105). The surveys were administered in the classroom at the end of the course.

Situational Intrinsic Motivation Survey: Guay, Vallerand, and Blanchard[36] developed this survey which asks for the individual to consider a specific situation and relate agreement to various statements about their motivation. The scale measures Intrinsic Motivation, Internal Regulation (doing something for your own good), Extrinsic Motivation, and Amotivation (not motivated). This survey is used to gauge aspect of motivation within SDT as it delineates the types of motivations students hold. This survey was given in IME 314 during Spring of 2015 and ENGR 300 during Fall of 2015 at the end of the term.

Miscellaneous survey questions: The surveys also included one question on the student's preference for the grading method and four questions about the level of stress in the course (see text box below). These questions were included because casual student comments were pointing to this grading method as a potential method to reduce stress for students. Michaelides and Kirshner[37] found that indeed grading method has the potential to reduce stress for students. The questions listed below were given in the IME 314 course in Spring 2015 and ENGR 300 course in Fall of 2015. The students were asked to respond with agreement on a 5 point Likert scale from strongly disagree to strongly agree.

Question about the grading method:

How did you like the grading method?

a. *I thought it was horrible*
b. *It was ok, I adjusted*
c. *I really liked it*

Questions about stress:

Please mark the extent to which you agree or disagree with the following statements: (5 point Likert from Strongly Disagree to Strongly Agree)

I stress less for this class than I normally do for engineering courses
The class has been a source of stress for me
I often stress about getting my work done
In general, I worry about schoolwork

Open-ended comments: During the Winter of 2015 in IME 239, we asked students for reflections on the grading method. The prompt was: "Give me your impression of the grading methods in this class." There were 40 reflections. We transcribed these comments and coded them using the three aspects: Mastery, Meaning, and Autonomy[38-40].

Results

Below are the results of the various evaluation techniques.

Course Valuing Inventory: This scale measures the value of the course. It is scored on a 5 point Likert scale (1 – strongly disagree, 2 – disagree, 3 - neutral, 4 – agree, 5 – strongly agree). For all three sections of the courses, Table 4 shows that the students on average felt that course had high value (an average between 4 – agree and 5 - strongly agree). The content learning was also consistently high (an average between 4 – agree and 5 - strongly agree). In the other categories, the students were closer to neutral in their assessment of the behavioral and personal learning (an average between 3 – neutral and 4 - agree). Unfortunately, there is no comparison group for this survey, but this does point to the possibility that this grading method adds to the value and learning in the course.

Table 4: Course Valuing Inventory

Course/Section/year	**N**	**Course Value**	**Content Learning**	**Behavioral Learning**	**Personal Learning**
IME 239 Spring 2013	30	4.06	4.21	3.59	3.60
IME 314 Spring 2015	45	4.08	4.06	3.33	3.07
ENGR 300 Fall 2015	28	4.70	4.54	4.05	3.71

SIMS: This survey measures motivation. This survey is scored on a seven-point Likert scale where a high value indicates higher levels of this type of motivation. The students are asked to indicate if a statement represents their thoughts or feelings about the course (1- not at all, 2- a very little, 3 -a little, 4 – moderately, 5 – enough, 6 -a lot 7 - exactly). In education, it is more desireable for students to have intrinsic motivation or internal regulation than it is to have

extrinsic motivation. Of course, we would prefer that no student is unmotivated (Amotivaiton). Table 5 shows the results of this survey.

Table 5: Situational Intrinsic Motivation Scale

Course/Section/year	N	Intrinsic	Internal regulation	Extrinsic	Amotivation
IME 314 Spring 2015	45	4.67	5.37	4.42	1.90
ENGR 300 Fall 2015	28	5.78	5.88	4.11	1.81

For the two sections that took this survey, the students express high levels of intrinsic and internal regulation (between 5 - enough and 6- a lot), slightly lower extrinsic motivation (between 4 - moderately and 5 – enough) and very low levels of amotivation (below 2 – a very little).

Preference for grading method: One item on the survey asked students to indicate if they liked the grading method. Figure 1 below indicates that a large proportion of them "really liked it" and only a few "thought it was horrible". There were 93 responses to this question.

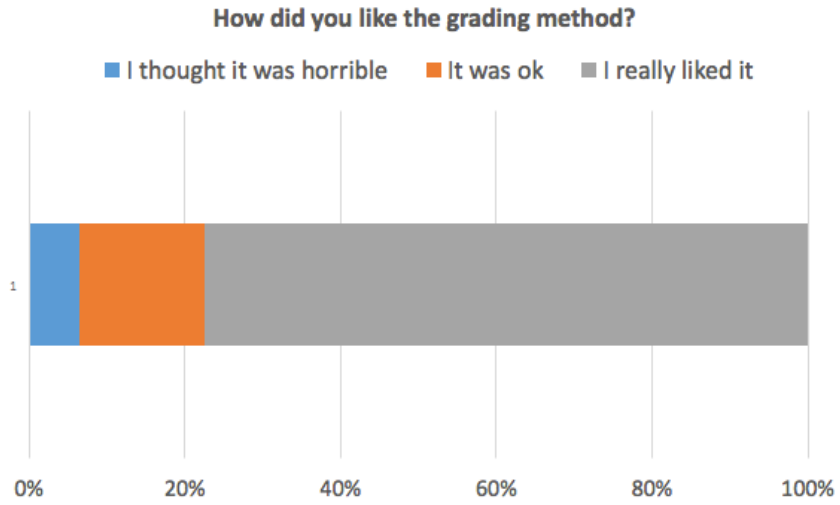

Figure 1: Preference for grading method

Stress: As it was indicated from antidotal comments, students were appreciative of the lower stress level that occurred because of the grading method. There are 4 items assessing stress in this and other engineering courses. There were 73 individuals who answered this set of questions.

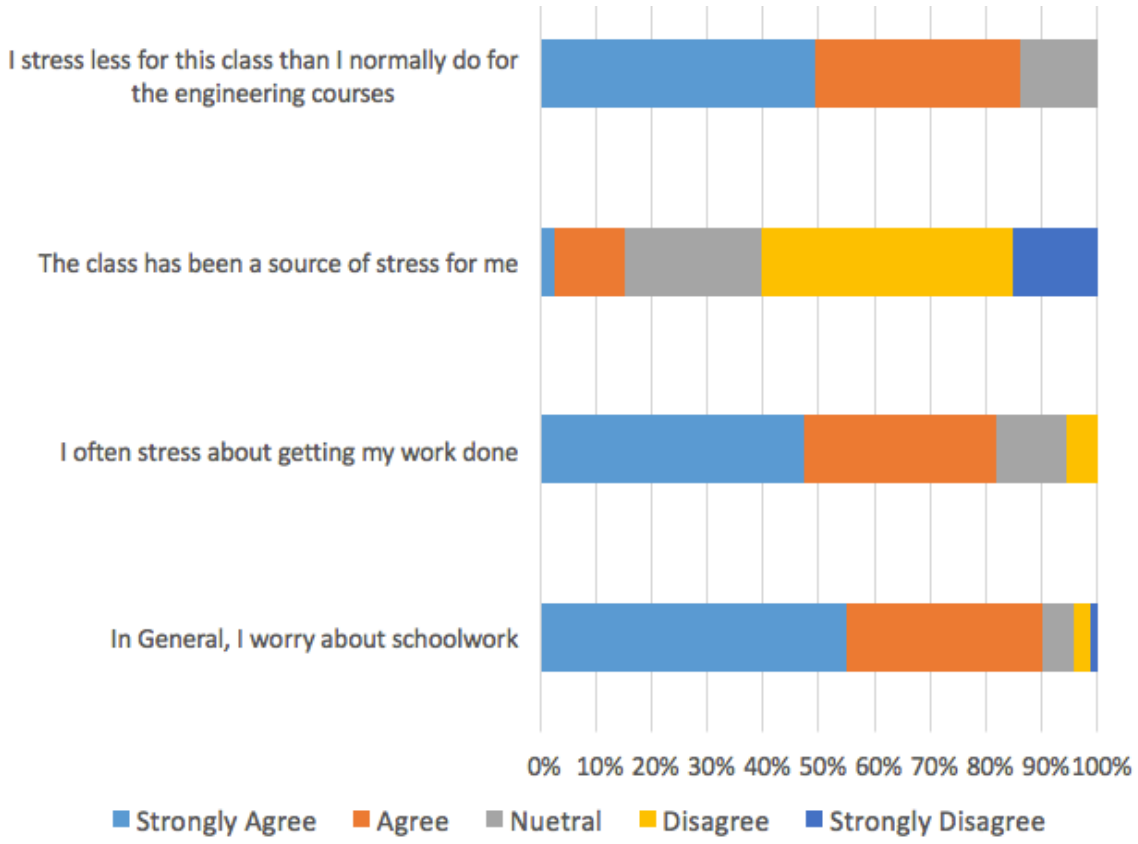

Figure 2: Stress

As can be seen in the bar chart (Figure 2) the students indicated that they usually feel stress in their schoolwork. Approximately 90% agree (or strongly agree) with the statement "In general, I worry about schoolwork" and approximately 83% agree (or strongly agree) with the statement "I often stress about getting my work done." However, when asked about the course with mastery grading, only 15% agree (or strongly agree) that "the class has been a source of stress for me", and 85% agree (or strongly agree) that "I stress less for this class than I normally do for my engineering courses".

Open-ended comments: The comments from the student reflections were reviewed and coded into the three categories (Mastery, Meaning and Autonomy) and another noticeable category about the lower stress level in the class. In addition, there were comments that didn't fit into any category. Figure 3 indicates the frequency of the comments.

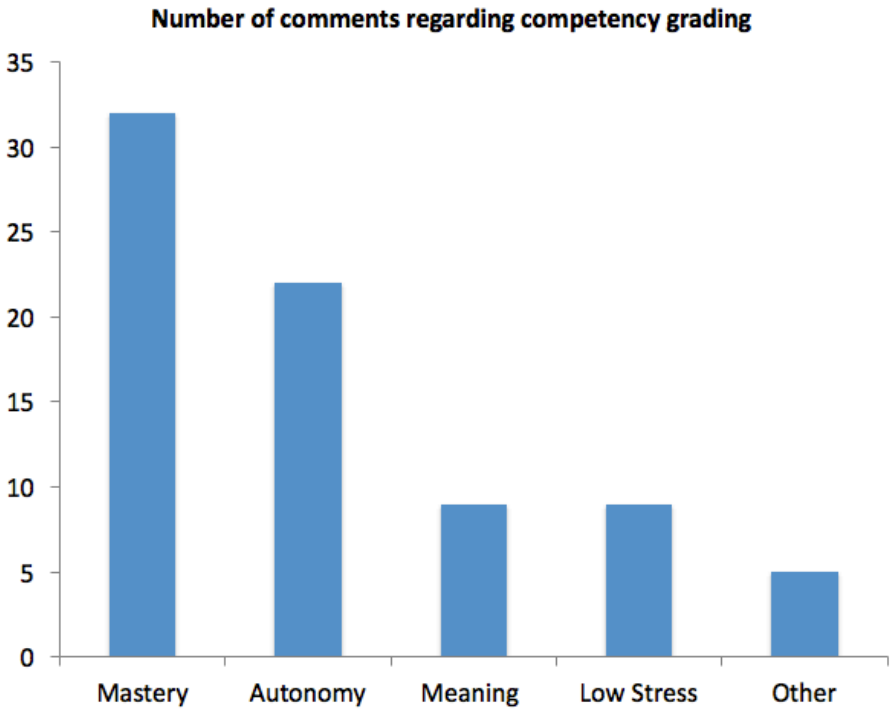

Figure 3: Qualitative comments coded using SDT

Some of the comments are listed below. Regarding "Mastery", students thought that they had a chance to learn the topics and were satisfied with the method of requiring a 90% level on the test. Surprisingly, no one commented on the inconveniences of retaking the test.

- *It makes sure the student has full mastery of the course material before they are awarded the units*
- *forces the student to learn the material*
- *It really makes you learn the material*

Students enjoyed working on projects that were of interest to them. They felt they learned a lot and were passionate about their learning. Below are comments about meaning.

- *I also love the flexibility on the projects. It let me learn so much about something I truly enjoyed.*
- *I liked that the topics of the reports weren't strictly given, but students could find a project/topic they are actually interested in*
- *I did two projects that I really was passionate about and I learned the material really well*

Students were very appreciative of the sense of control over their grade. Below are example comments about autonomy.

- *Up front, you knew how hard you need to work in order to get a certain grade*
- *It is nice knowing I have control over my grade*

- *I think the grading method is great because you are in complete control of your grade based on how much time and effort you are willing to put in the class*
- *Having our grade in our own hands, for once, is refreshing*
- *I felt in control of my grade which is a really nice change*
- *It gives you a chance to know you can 100% get an A if you put the time in and do the work*

The students commented on the low stress with the grading method and how they could manage the demands of this course.

- *I could adjust my schedule easily.*
- *I think it really forces you to actually learn the material in a low-stress environment*
- *Making this class very flexible brings a positive attitude to this class (at least for me J)*
- *Somehow I actually learned something but wasn't super stressed all quarter*
- *I didn't stress over midterms, instead, I made sure I knew the material*

Students had other comments regarding the grading which are listed below.

- *it might not be the best grading method for students who don't care*
- *I enjoy the grading methods, [but] it did allow me to be more lazy*
- *I had a hard time doing the two projects throughout the quarter*
- *there could be some other "reward" or something fun for coming to class. Like if you come for x amount of days you get +5 on the final, just to encourage more people to come!*

Discussion

We hope that this discussion about grading will lead to a larger discussion about the assumptions we hold and the unintended consequences of what we do in the classroom. We believe that Mastery Grading is a good place to start to think about the subjective nature of grading. It may help us move to a system that encourages the skills and abilities that students need as they maneuver an ever changing world. In addition, it requires students to acquire knowledge at a deep level in order to pass the class. This rigor is necessary for much of engineering.

The evaluation of this grading method is still a work-in-progress, but the evidence collected thus far indicates that the method has much potential for enhancing learning and creating an environment that is less stressful and one that allows for more creativity, innovation, and life-long learning. The grading method enhances intrinsic motivation by increasing opportunities for Mastery, Autonomy, and Meaning. In mastery grading, the control of the grade moves to the student and the role of the instructor becomes more of coach and mentor. There is no longer an adversarial role, but a support relationship.

There are a couple things that change for the faculty member with this grading method. The first is a very practical one, in that we have to write more test. However, this is balanced by the fact that there is no longer a need to grade and track the detailed assignments. For the IE courses, there are 4 grades entered into the grade book all quarter, the two midterms and the two projects.

The grades are all pass/fail so there is no weighted average calculation. A real benefit is that students almost never argue about a grade. They know the grade they are getting and they know it is their responsibility.

As this is a work-in-progress paper we want to acknowledge the limitation of the data presented. At this point, there is no experiment defined or control group for comparison. The evaluation methods used to date, point to some positive aspects of the method, but will need to be further vetted. As in any research, there seem to be more questions created than answered. Below is a list of some of these questions.

- What is a good way to evaluate, measure the impact of this grading method?
- Does this method work with all students?
- Are there individual differences in student perception of this grading method?
- Does this method change student's perception of grading or grades?
- How is grading related to teaching practices?
- How is grading related to the assumptions faculty hold about students[41]?
- What is the current state of grading practices in engineering education?
- How should we grade innovative work?

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