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Privileging Learning Over Numbers: Developing an Alternative Student Assessment in Engineering

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Privileging Learning Over Numbers: Developing an Alternative Student Assessment in Engineering Education

In this research study, an alternative approach to assess student performance and academic learning in engineering disciplines is proposed with the intention of shifting a grade driven mentality into a learning-oriented mindset. The rationale for this model of assessment is to disrupt normalized assessment practices in higher education, reframe student thinking regarding learning and acquisition of knowledge, and encourage students to engage in coursework in meaningful ways. Unfortunately, grades in higher education have become a primary focal point for many students as a means to secure internship opportunities, undergraduate research, post-graduation employment, and graduate school acceptance into desired institutions. The downside of such a grade-based orientation is that anxiety, stress, and memorization have overtaken the essence of attending higher education to acquire valuable knowledge and skills needed to become a well-trained professional. 88% of the students surveyed in this study memorize course material in order to pass any sort of assignment, which means that student learning and retention of fundamental principles are at risk. As such, the authors have developed a preliminary model in which students receive an assessment sheet for every homework assignment and exam rather than a grade. This assessment sheet provides detailed feedback on the procedures and calculations performed correctly and incorrectly, and it is based point-scale from 1 to 4: (4) flawless work, (3) quality work, (2) average work, and (1) needs improvement. This assessment sheet is targeted to increase student awareness on the technical areas in which they need to improve and provide opportunities for continuous growth and successful progress. Once students receive their assignments, they have the option to revise their work and correct any errors. Survey results from this study reveal that this alternative student assessment relieves pressure and helps counteract self-inflicted stress and anxiety, while promoting student efficacy and increased competence and knowledge of engineering content and principles.

I. MOTIVATION AND BACKGROUND

Receiving a college degree may lead to securing employment post-graduation, or acceptance into graduate school. However, being able to access these opportunities generally requires participating in co-curricular activities that will enhance students' learning experience, deepen their technical skills, acquire real-world experience, and strengthen professional competence [6], [9], [10], [22]. For most students pursuing STEM related fields, it is common to target at least one internship position before graduation in order to attain relevant experience and increase the likelihood of employment [3], [4], [9]. These opportunities are generally granted to students who have demonstrated minimal expertise in a specific technical area. As such, a large number engage in specific design clubs or competitions in their respective institutions to enhance their experience in design and/or leadership roles, and thus attract employers of interest [6], [10].

Other students engage in undergraduate research opportunities as an alternative venue given its immediate and long-term benefits [5], [6], [12], [17], [25], [27], [32]. Research efforts indicate that undergraduate students participating in research obtain greater confidence in research and professional abilities, attest awareness of a graduate school environment, gain significant growth

in structuring and conducting research project, and pursue STEM careers and Ph.D. studies post-graduation [3], [25], [26], [27].

Nonetheless, procuring internship positions, joining research groups, or being accepted into graduate school, highly depends on maintaining a competitive grade-point average (GPA). Grades in higher education are of extreme value since they open doors to a host of career and development opportunities [7], [10], [19], [23]. However, the risk of meeting such demand pose short-term and long-term emotional impacts on student behavior. Studies reveal that a sense of apprehension, depression, and anticipating the worst are emotional effects experienced by students trying to meet grade demands [30], [31]. Similar studies report anxiety, increased mental exertion, and physical exhaustion as negative effects associated with emotional behavior. According to Barlow, anxiety is defined as an unpleasant feeling of nervousness, apprehension, fear, concern or worry [2]. It can serve as a motivator to overcome a current demanding situation, or it can have a serious impact on daily life and influence performance levels [30], [31]. Hembree, for instance, reported that high levels of test anxiety are negatively correlated with various cognitive components such as IQ, problem solving, memory, aptitude, need for achievement, locus of control, school environment, ethnicity, sex, birth order, test conditions, ability level, matching format, and grades [15].

From the literature findings, the authors posit that the emotional impact of grades may further affect student learning and retention rates [11]. Significant research has been conducted to address the need of increasing retention rates in engineering education [10], [11], [13]. Several pedagogical methods, for example, have been incorporated to enhance student comprehension and scholarship abilities [34]. A known method incorporated in various academic fields is Problem-based learning (PBL), which focus towards acquiring knowledge and developing self-directed learning capabilities and critical thinking skills through various mediums such as problem solving, interpersonal skills, and team skills [21], [33]. Despite its impact on student learning and educational environment, PBL is not frequent amongst engineering educators due to its unfamiliarity. Thus, alternative pedagogical schemes such as Project-based learning, incorporating visual supplements during lecture sessions, and establishing communication channels have been utilized to promote learning and retention rates in engineering education [18], [20], [21], [33], [34].

However, the authors observe that engineering students may consequently disengage from lecture sessions, or from the entire course, due to the emotional impact of grades, regardless on the effectivity of various pedagogical schemes [1], [2], [15], [24], [28]. In a pilot study conducted by Marquez and Garcia, the short-term effects of grades on engineering students were evaluated during the progression of a semester, that is, at the start, during, and at the conclusion of the course [19]. The study was intended to understand the emotional state of the student when grades are factored into their coursework, and the potential actions they may consider to remedy undesired outcomes. Results indicated that 60% of the surveyed population experienced a sense of anxiety regarding grades at the start of the semester. The study then analyzed the emotional impact when grades were as expected and unexpected mid-semester. Results indicated that 52% of the surveyed population conveyed a level of concern with grades moving forward despite having expected grades. This was a critical finding given that academic or emotional concern is generally associated with low scores, not high scores. On the other hand, 96% of the students expressed concerned when grades were not as expected mid-semester. The research study also intended to extract details

regarding the plan of action students might consider when grades were not as expected. Results indicated 56% of the surveyed students will study more, 20% will pass/fail the course, 12% will seek assistance with the teaching assistant or instructor, 8% will pay more attention, and 4% will stop caring for the class. These findings were imperative given that they may be associated with student disengaging from lecture sessions or from the entire course.

II. PROPOSED WORK

Thus, it is noted that a high grade-point average is the pathway for career advancement and professional development opportunities [7], [8], [10], [17]. As such, undergraduate engineering students tend to prioritize much of their time and effort securing high grades and partaking in various co-curricular activities. While numerous students realize their goals of earning high grades, others fall short of their scholarly interest [8]. As such, the authors observe both short-term and long-term psychological effects when students' desire to attain high grades becomes the focal point (Figure 1). When this is the case, negative effects such as anxiety, mental exertion, depression, fear, concern, and worry tend to effectuate [7], [14], [29]. This emotional pattern leads to irrational and poor-decision making in which students frequently recur to memorization, for instance, in order to appropiate assignments. Other students gravitate towards violating the honor code as a desperate measure to maintain high grades, while several tend to drop courses or change majors. All sorts of temporary resolutions lessens students' motivation and ability to focus, learn, and fully engage in course material.

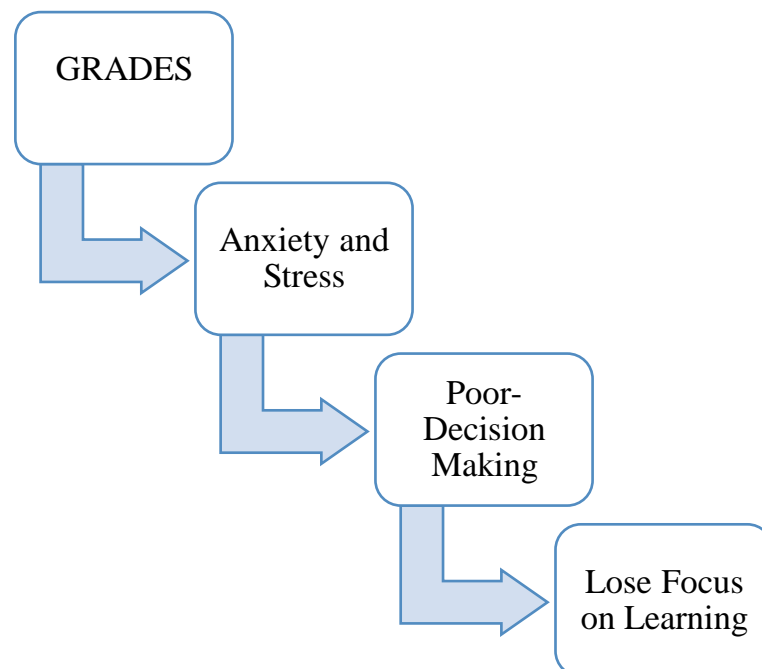


Figure 1. Effects of Grades on Student Performance

Despite the ongoing efforts of identifying the emotional effects generated by grades [7], [14], a limited number of studies address the actual problem of reducing grade anxiety, particularly, in engineering related disciplines where anxiety issues seem to be higher than other fields. As such, the authors propose an alternative approach to assess student performance and academic learning in engineering disciplines with the intention of shifting a grade driven mentality into a learning-oriented mindset. The rationale behind this assessment model is to disrupt normalized assessment practices in higher education, reframe student thinking regarding learning and acquisition of knowledge, and encourage students to engage in coursework in meaningful ways. Thus, the proposed assessment scheme is composed of three fundamental categories: 1) Scale change, 2) Feedback and Revision, and 3) Evaluation session (Figure 2).

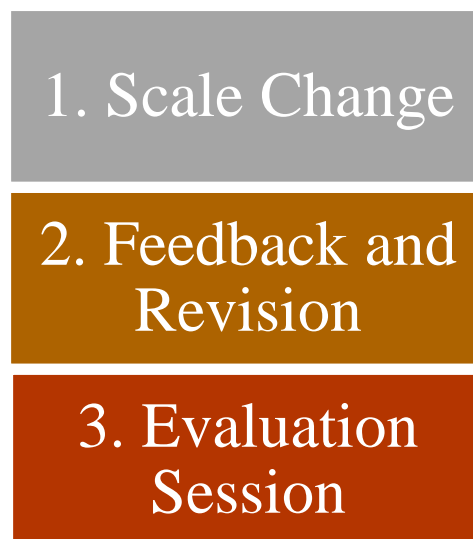


Figure 2. Proposed Assessment Scheme

Category I

The intention of category one was to substitute the traditional grading scale (e.g., 0.0 – 100 pts.) with a point-scale system (1.0 – 4.0 pts), and gradually shift the grade mentality into a learning disposition. In the proposed point-scale system, a 4.0 represented ‘flawless work,’ 3.0 represented ‘quality work,’ 2.0 represented ‘average work,’ and 1.0 represented ‘needs improvement.’ The motivation behind its integration was to emphasize the need of submitting quality assignments rather than attempting to maximize the number of points on specific problems. In addition, the assessment scheme was developed to increase awareness on technical areas of improvement and provide opportunities for continuous growth and progress. As such, the instructor created an assessment sheet which delineated various technical and learning outcomes for each assignment (Table 1, Section 1). The ‘Yes’ and ‘No’ columns were checked by the graders if the corresponding outcomes were met or not.

Table 1. Sample Assessment Sheet for each Assignment

Section 1: Evaluation	Yes	No
1. Included Reference Frame on all the applicable problems. This includes labeling the positive x, y, and z axes and their respective directions. FBD's are correct		
2. Used Factor of Safety Equations correctly for all applicable problems.		
3. Internal forces/torque of members were found correctly for all problems		
4. Deformation/stress equations were applied correctly for all applicable problems		
5. All final answers included proper UNITS and correct directions (positive/negative)		
6. All the steps were clear and made sense. Student had a clear idea of solving the problem		
Section 2: Comments:		
Point Scale:		
4.0 Flawless Work (6/6)		
3.0 Quality Work (5/6)		
2.0 Average Work (4/6)		
1.0 Needs Improvement (3/6)		

Based on the proposed scale, the instructor confirmed that having an overall average of 2.0 or higher at the end of the semester, guaranteed students earning a letter grade of B or higher. However, it was emphasized that students earning a 1.0 had to resubmit the corresponding assignment and correct technical faults. The aim was to convey that learning and submitting technically sound assignments is far more significant than simply attaining 'high' grades, and simultaneously, relief self-inflicted stress and anxiety, promote student efficacy, and increase competence and knowledge of engineering principles.

Category II

In addition to the learning outcomes, the proposed assessment sheet contained a feedback section (Table 1, Section 2) in which teaching assistants were recommended to comment deliberately on mathematical errors and technical discrepancies. Such detailed annotations establish a clear path of identifying areas of improvement on each assignment. Students were also granted permission to revise their assignment, even if a score of 2.0 or higher was attained, to ensure an absolute comprehension of related themes and technical content. When undesired grades are attained, there is a general tendency of dismissing the assignment and avoid reviewing specific errors. However, learning is an iterative process which requires time to fully develop, thus it is imperative that students identify and ameliorate their errors.

Category III

A casual, one-on-one [evaluation] session was hosted a week prior to the semester concluding, in which an estimated letter grade was reported to the student. This preliminary breakdown indicated their standing in the course prior to the final exam, though it was repeatedly emphasized throughout the semester that points above 2.0 represented a B or higher. This was frequently mentioned to diminish anxiety about the removal of grades. For the evaluation session, students were recommended to collect homework, quizzes, exams, and revisions in a binder; allowing the instructor to evaluate the progression throughout the course. However, this individualized approach also provided students' a more holistic and comprehensive view of their own learning progression that took place during the semester span.

III. METHODS AND ANALYSIS

For this pilot [research] study, the authors employed a two-step process to gather student data and construct an alternative structure to assess student learning. A mixed methods research design was utilized to understand the perspectives of engineering students toward the acquisition of grades and views of learning. The context of the study effectuated in a small, private (four-year) institution in Texas. The sample selection consisted of 45 undergraduate students enrolled in an introductory mechanical engineering course, which were classified from freshman to sophomores. The primary method of data collection was a self-developed survey instrument that was administered to the cohort of students.

A preliminary study was conducted to better understand student perspective on learning, memorization, and grades. For the authors, this preceding study was critical in conceptualizing the alternative assessment scheme which aims to reduce grade anxiety and promote learning in the classroom. A total of five, self-developed questions were delineated in the study (Table 2). These questions were designed to provide insight into students' perspectives regarding grades and attitudes towards learning course material. The corresponding open-ended responses were employed to provide an opportunity to share in detail their views and perspectives regarding the three proposed evaluation categories: 1) Scale change, 2) Feedback and Revision, and 3) Evaluation session.

Table 2. Questions of Preliminary Study

Question 1: How important is it for you to obtain good grades?
Question 2: How important is it for you to learn the material?
Question 3: What is more important to you?
Question 4: Have you memorized material just to pass an assignment?
Question 5: Do you feel that memorizing is good for you in the long-run?

The student survey was informed by the work of Nist and Diehl Test Anxiety Questionnaire [16]. The short questionnaire was developed who assess degrees of student anxiety related to academic indicators specifically tests and assessment related outcomes.

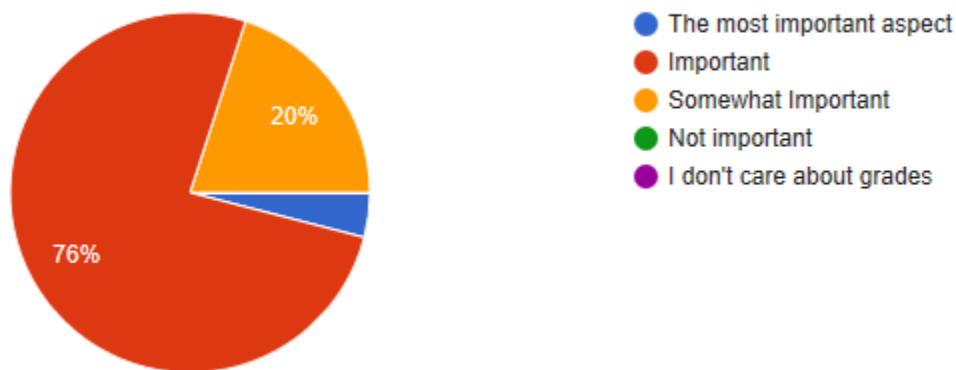
Limitations of Study

The authors identified the following limitations of the study: small sample size; replicability of the study is limited to engineering students; lack of a comparison group to perform a T-Test for group differences; data collection was limited to surveys; and study was limited to students enrolled in one engineering course.

IV. RESULTS

Part I: Results for Preliminary Study

Question 1: How important is it for you to obtain good grades?



For question one, a total of five response options were outlined: 1) the most important aspect, 2) important, 3) somewhat important, 4) not important, and 5) I don't care about grades. This question, and those subsequently, were informed by Nist and Diehl's student anxiety questionnaire in which items were based on a 5-point Likert-Scale format with the following coding: Most important aspect (5), Important (4), Somewhat important (3), Not important (2), and I don't care about grades (1).

Results indicated that 100% of the surveyed students considered earning good grades relevant in their coursework and a pathway for career advancement and professional development opportunities. Four percent indicated that obtaining good grades was the most important aspect, 76% specified that good grades were important, and 20% acknowledged earning good grades was somewhat important.

Open-ended responses to Question 1 alluded that high grades were necessary in procuring internship positions, employment, and graduate school acceptance. A particular student mentioned

the unfortunate reality that grades are how students are judged during matriculation or post-graduation, and as a result, it is critical to take them seriously.

“High GPA = High chance of employment”

“Need to maintain good grades for internship and grad school”

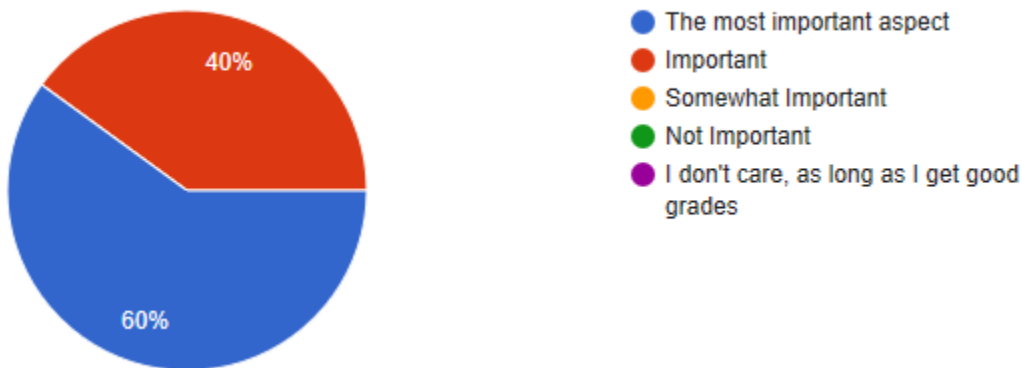
“I know it’s fairly important right now in obtaining internships, but later down the road other skills come into play”

“At the end of the day grades are how you are judged, so it’s an unfortunate reality that you have to take them seriously”

“I know grades are important towards internships and jobs”

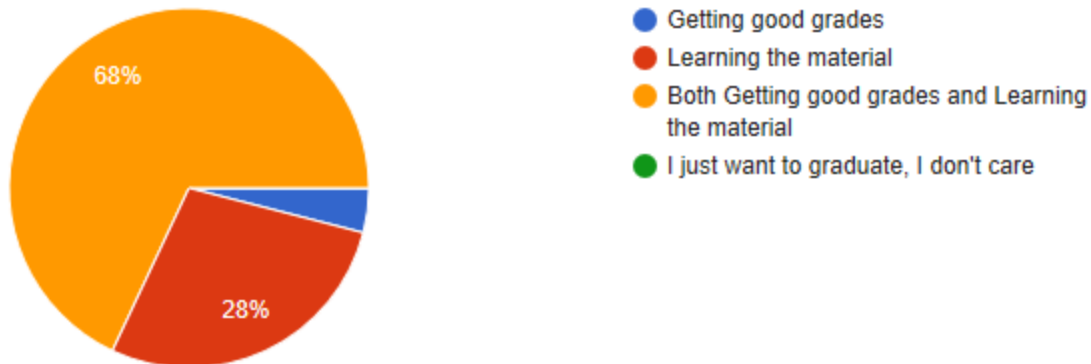
“Without good grades I will not get the opportunities I need to achieve my goals. Honestly, I find myself pushing towards that grade too frequently”

Question 2: *How important is it for you to learn the course material?*



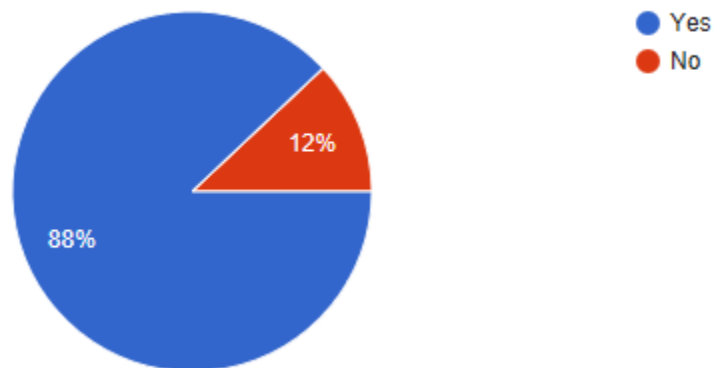
For question two, a total of five response options were outlined: 1) the most important aspect, 2) important, 3) somewhat important, 4) not important, and 5) I don't care, as long as I get good grades. Results revealed that each student considered learning an important aspect of their education. However, 40% recognized that learning was only an important aspect, and not the most important aspect. This finding may suggest that students consider adopting various alternatives such as memorization or honor code violation such that desired grades are attained without much effort.

Question 3: *What is more important to you?*



For question three, a total of four response options were outlined: 1) getting good grades, 2) learning the material, 3) both getting good grades and learning the material, and 4) I just want to graduate, I don't care. Results indicated that 28% of the students considered learning course material an important condition, and 68% mentioned that earning good grades combined with learning the material were essential elements to success. Nonetheless, 4% of the population acknowledged that attaining good grades was the most important aspect in the course, and was above learning. This outcome may reveal that students' perspective on learning is not a priority as attaining high grades, which may further influence the engagement during lectures and the retention of fundamental engineering principles.

Question 4: *Have you memorized material just to pass an assignment?*



The fourth question inquired about memorization. Nearly 88% of the surveyed students acknowledged that memorization of course material was a method utilized to assist in passing an assignment. According to Bloom's taxonomy, which is a conceptual framework that differentiates six types of domains of thinking and learning, memorization is the lowest form of thinking. Due to its characterization as a lower-order skill, memorization is short-term based and is focused on

recall of information and does not tap into deep levels of learning and acquisition of knowledge, which is vital for engineering disciplines.

Question 5: *Do you feel that memorizing material is good for you in the long-run?*

In the open-ended responses to Question 5, students indicated that memorization is not a beneficial act to improve their professional development in the long-run. However, they acknowledged being forced to memorize to attain short-term success on exams. Others utilized memorization to ‘cut corners’ when course material was excessive and difficult to understand.

“Memorizing is helpful in some areas, but in other areas like coming up with a novel solution to a real world problem, it is less helpful”

“No, I usually forget the material pretty soon after I just memorize it”

“No, I definitely don’t think it is good for me to memorize material in the long run but I am forced to memorize stuff because I am graded by how I do on my exams in the class only”

“Not at all, but we all do it. Certain things are time consuming to fully grasp, so we tend to cut corners and memorize them”

Part II: Results for the Alternative Assessment

While the vast majority of the students mentioned that learning and getting good grades are equally important, others mentioned that the most important aspect in education, at the end of the day, were grades, particularly, since they are critical for career advancement and professional development. As such, students rely on alternative solutions such as memorization to main a high-grade-point average. Thus, the authors conclude that the alternative assessment scheme should focus on decentralizing students from grades, reduce anxiety, and promote learning. For such scheme, open-ended responses were employed to provide an opportunity to share in detail their views and perspectives regarding the three proposed evaluation categories: 1) Scale change, 2) Feedback and Revision, and 3) Evaluation session.

According to the open-ended responses, the alternative assessment scheme seemed to benefit students in various areas. For instance, a large number of students agreed that the assessment scheme was able to alleviate a significant amount of stress from the traditional grading scale, which has a tendency to demotivate students when a handful of chances may decide a course grade, or when a single unfavorable grade in the course may reduce the likelihood of earning a desired [final] grade. By deliberately centering student learning as the focal point of the course, the alternative assessment framework help to disrupt the pervasive nature of the traditional grading scheme that centers and privileges outcomes rather than student learning. This assessment format engendered a learning environment in which students felt comfortable, relaxed, and confident. A notable shift occurred in students’ outcomes-oriented mindset to a more organic, process-oriented mentality in

which learning, and the acquisition of knowledge was the desired result. As such, students were able to focus on learning, understanding the material, and applying concepts to real-world problems rather than trying to maximize the number of points earned on homework or exam questions. This pressing feedback suggest that numerous engineering students are inclined towards adding unnecessary data into their assignments to simply earn extra-credit points.

Students further noted that written feedback on assignments was of particular help in understanding their technical errors, while having the ability to revise them was beneficial towards learning the material. Such reactions suggest that being able to work on problems for a second instance may increase retention rates in engineering education. Another student mentioned being encouraged to study more with the alternative assessment scheme, while others attested having their thought process and analytical ability challenged when solving problems. One particular student mentioned that the alternative assessment scheme allowed everyone to be treated on the same platform, meaning that the notion of competing for grades was eliminated.

Open-ended responses also indicated that the new assessment was a bit ambiguous in category three, particularly, since students' actual letter grades were revealed until the last week of class during an individual session with the instructor. Students agreed with the idea of implementing a scale change and feedback/revision as an alternative scheme, but preferred having consecutive [evaluation] sessions throughout the semester rather than a just single one at the end. The inclusion of a series of sessions will respond to student learning needs and support their academic growth and development. This insight provides valuable feedback that will help inform future implementation and modification of the assessment scheme.

“I like the idea of having a point-scale assessment sheet because it puts every student on the same level. In my other classes I feel inferior to my peers because I know they're smarter than me. But with this assessment, I feel at their level and more confident learning the material.”

“I just love the idea of focusing on learning. Grades definitely add more stress.”

“Took off some stress of always having to worry about getting a perfect grade on every assignment, which forces students into the mindset of just doing whatever necessary to memorize the material in order to pass the exams, and then forgetting everything once the class is over.”

“The grading system was a bit ambiguous what exactly our grade was going to be until the last week of class, at which point our only opportunity to change it was the final exam.”

“Maybe have a few more opportunities for meetings throughout the semester for students who want to know where they stand.”

“This new way of assessment is great. I just feel sad because I know that after I finish this class, I will go back to worrying about grades.”

“Every single class I have enjoyed and actually challenged me in a purposeful way. Exams are more designed to test my thought-process and analytical ability rather than my memory.”

“I liked feedback on every assignment. It gave me a great understanding where I messed up on the problems.”

“At first I was very skeptical about the approach, but once the semester started, I really liked the idea. It actually made me study more.”

“I liked the idea of learning. It has happened that I memorize material for the exam to earn a good grade, but after two weeks, I can’t remember anything.”

“I stand by saying that I liked the system not worrying about grades. This has actually helped me do better in other courses. Old habits die hard, of course, so I did worry about some about my grades towards the end.”

“I really appreciated being able to re-do our work.”

“I appreciated a lot. As someone who had some struggles in the class, having effort be the focus helped to ease my stress.”

“I really appreciated the lack of pressure that not having grades on assignments allowed. This made me learn concepts better since I focused on applying the material learned to real problems rather than looking at how to maximize the most points I could get for a Homework or Exam question.”

“The written feedback that was given on the assignments along with the opportunity to correct them, helped me learn what mistakes I made and how to correct them in the future.”

“I thought that the new approach was very innovative. Personally, I felt that it took the pressure out of having to focus on deliverables and instead focus on understanding the material.”

“Taking away formal grades really took a lot of stress out of the class. One of the most demotivating parts of class is when a single bad grade nukes a chance at an A in the course. But by taking the emphasis off grades and putting it on learning, it allowed students to

learn better without feeling pressured by a feeling of only having a certain handful of chances to decide their course grade.”

V. CONCLUSION

In this research study, an alternative approach to assess student performance and academic learning in engineering disciplines was proposed with the intention of shifting a grade driven mentality into a learning-oriented mindset. The rationale for this approach of assessment was to disrupt normalized assessment practices in higher education, reframe student thinking regarding learning and acquisition of knowledge, and encourage students to engage in coursework in meaningful ways.

Results from the preliminary survey assisted in finalizing the alternative assessment scheme proposed in this paper. Most surveyed students mentioned that learning and earning good grades were equally important, while others mentioned that grades were by far the most significant aspect, and thus necessary for career development and professional development.

As evidenced by student feedback, the creation and implementation of an alternative assessment structure has reduced anxiety and help strengthen students' prioritization of learning. The findings reveal that students engaged with course material in more meaningful and thoughtful ways, which allow them to focus primarily on learning course content. Moreover, students expressed favorable views towards the inclusion of a point-scale system when compared to the traditional assessment scales. The results indicated that the point-scale system helped to 'level the playing field' and minimize psychological issues such as self-efficacy, anxiety, and motivation that often serve as barriers to meaningful learning and active engagement.

Results also indicated that the new assessment was a bit ambiguous from the perspective of category three, particularly, since students' actual letter grades were revealed until the last week of class. Students agreed with the idea of implementing all three categories of the new scheme, but preferred having more evaluation sessions throughout the semester rather than a single one at the end.

Future Work

Based on the findings of this study, the authors have identified two additional modifications that will strengthen and expand the impact of the alternative assessment structure. The first modification is the inclusion of a more robust assessment sheet (Table 1). For this modification to effectuate, the authors will conduct a survey with the current cohort of students to attain feedback regarding the effectivity of the current [assessment] sheet. It is imperative that the feedback section encapsulates every technical detail associated with the corresponding assignment.

The second modification to the alternative assessment scheme is the integration of more evaluation sessions throughout the semester (e.g., category three), which will allow students to know their academic standing in the course early in the course. For this particular accommodation, the authors are planning to include a thorough evaluation session regarding the comprehension of lecture material and assignments for each student. As such, the integration of these two modifications will be implemented and evaluated in subsequent semesters.

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