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WIP: Implementation and Student Perception of Specifications Grading in Mechanical Engineering Courses

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Abstract

This work in progress paper discusses the implementation and student perceptions of a specifications grading scheme in three Mechanical Engineering courses. The student perception was measured quantitatively using a recently published Perception of Grading Schemes instrument, with supplemental qualitative data from course evaluations gathered by the university. Data shows strong agreement between predicted and measured benefits to specifications grading, though measured student motivation to learn falls short of expectations.

Introduction

Specifications grading is a grading system in which assignments are graded pass/fail, based on pre-defined specifications [1]. It attempts to directly link grades to course learning outcomes, and often comes with a system that allows students to retake assignments or exams. Groups of assignments are often "bundled" into modules. Completion of a certain number of modules can then be used to determine a final letter grade. It is a flexible paradigm, which is easy to modify to fit a course or instructor.

Specifications grading has been theorized to have many benefits to both students and instructors [1]. For students, these benefits include reduced stress/anxiety, increased student motivation to learn/excel, clearer expectations from instructors, and better/more useful feedback. Additional benefits for instructors include saving faculty time, authentic assessment, increased student ownership of grades, and reduced conflict between instructors and students.

Specifications grading has been investigated most widely in Chemistry and Engineering, and primarily in classes of 35 or fewer students [2]. Howitz et. al. describe four different configurations within grading schemes, including the "core and additional learning outcomes" and "modules" used in the present work [2]. Other configurations are based around learning outcomes being equally weighted. A challenge with the existing literature is that most investigation is performed through ad-hoc surveys or qualitative course evaluations, which are difficult to compare or combine. The Perception of Grading Schemes (PGS) survey described in [3] provides a validated and standardized instrument to measure some of the listed benefits.

In this work, a specifications grading scheme has been implemented in three Mechanical Engineering courses (Fluid Mechanics, Thermodynamics, and Heat and Mass Transfer) at Abilene Christian University, a private R2 university. Each of the classes has a slightly different approach, developed to target various student outcomes in the three classes. All three classes include both exams with retake opportunities and project-based learning.

Grading Schemes

The full grading scheme for all three classes is outlined in Appendix A. In each of the grading schemes, the course is split topically into modules, each of which culminate in an exam. For each course, passing the first three modules (roughly 60% of the class by time) is required to obtain a “C”, while additional modules are considered “add-ons”: extra content which may be completed to earn a higher grade. Passing a module is defined in both Fluids and Heat and Mass Transfer as completing all online quizzes with a perfect score and scoring 80% or higher on the module exam. For Thermodynamics, it is defined as scoring 7 of the 9 points available on the two quizzes (two points each) and exam (five points) in the module.

The courses have varying numbers of projects, all of which have small (1-2 page) writing components, except for the “large” project in Fluid Mechanics, which requires a longer (7-10 page) report. Each class has one project that is required to earn a “C”, while the other projects are again classified as “add-ons”. The required project is convenient for ABET assessment purposes.

Additionally, there are “testing criteria” for each class, intended to encourage students to perform their best on the initial in-class exams and quizzes. These vary by class, but typically include options such as “pass two exams on first try” and “pass (cumulative) Final Exam.” Testing criteria are only required for “A” and “B” grades. In the Fall 2025 section of Fluid Mechanics, the cumulative final exam was the only option provided, with a score of 50% required for a “B” and 75% required for an “A”. This made the final have an outsized impact on student grades. Passing exams (and quizzes in Thermodynamics) on the first try was added as a substitute for final exam performance in later semesters and classes.

A token system is used to provide limited retakes on in-class assessments and project resubmissions. Online quizzes have free retakes, while the number of tokens required for in-person exams and quizzes is tuned such that a student that earns all tokens in a course can retake all required exams and quizzes one time.

Retakes are administered during office hours, and students may take as much time as they need to complete the exam or retake, subject to my availability. Students may check their answers at any time, and no partial credit is awarded. I also allow students to ask me one question on the exam for an additional five tokens (clarifying questions are free). If a student cannot reach their desired grade, they must attempt an additional retake. The student’s new score is used to calculate module completion, but is not used for the “testing criteria”.

A soft deadline is set at two weeks after the in-class exam or the Monday following the last class day, whichever comes first. Attempting a retake after that time costs an additional five tokens. This encourages students not to fall too far behind or procrastinate, without being overly penalizing for students who accidentally miss the deadline.

There is additional workload in grading retakes. However, it is mitigated by the real-time feedback provided, as only the final answer needs to be checked. Additionally, partial credit is only awarded on the first try of an exam, with full points awarded for a complete and correct answer, half points if math or other non-conceptual errors are present, and no points if a conceptual error is present.

Student Perception of Grading Schemes Data

The recently published Perception of Grading Schemes (PGS) instrument [2] was administered to students, collecting information on student perception of the grading scheme. The pilot version of the instrument was chosen primarily to investigate responses to several of the questions cut from the updated instrument, specifically Mot6 - “I am motivated to aim for a higher letter grade.” and Res2 - “It is up to me to earn the letter grade I want.”.

The factors investigated by the PGS instrument are coded as follows:

- Out - Reflect student learning outcomes
- Mot - Promotes motivation to learn (original questions labeled Mot1-3)
- Anx - Raises anxiety
- Fbk - Useful feedback
- Exp - Clear expectations

Additional factors which are investigated in the pilot version of the PGS study are:

- Con - Reduces conflict between instructor and student
- Res - Results depend primarily on student effort
- Gmt - Promotes motivation to earn higher grades (original questions labeled Mot4-6)

Data from the PGS instrument, alongside a FERPA release, were collected from 19 students in Fluid Mechanics out of 38 total students. Each of the responses was given a score between -1 to 1 as shown in Table 1.

Table 1. Scoring of Responses to PGS instrument

“More representative of traditional grading”	-1.0
“Slightly more representative of traditional grading”	-0.5
Equally representative	0
“Slightly more representative of specifications grading”	0.5
“More representative of specifications grading”	1.0

The data were collected into an overall PGS score, along with averages of subsets of the data. For questions that were negative in nature (Gmt1, Anx1, Anx2, Anx3, Res1, Con1, Con2, and Con3), the scoring was inverted when averaged. The full list of questions can be found in the supplementary information of [2].

The confidence interval of each subset average was calculated using a t-test and is provided in Appendix B. Strong evidence was found that the grading scheme was generally viewed positively ($p=0.000004$), lowered anxiety ($p=0.00003$), encouraged student ownership of grades ($p=0.00008$), and clarified course expectations ($p=0.00009$). Weaker, but still significant evidence was found that the grading scheme reduced conflict between the students and instructor ($p=0.017$) and reflected the course outcomes ($p=0.019$). The data does not support conclusions that the grading scheme encouraged use of feedback ($p=0.095$), promoted motivation to earn a higher grade ($p=0.795$), or promoted motivation to learn ($p=0.925$).

For most of the subsets, the results for the average were representative of the individual questions. However, that was not true for the two motivation subsets (Mot and Gmt). The data for the individual questions is also provided in Appendix B. The strongest data suggests that students were more motivated to aim for a higher grade in the class (p=0.018), but less motivated to perform their best on each assignment (p=0.090).

In addition to investigating the average effect of the grading scheme on all students, an attempt was made to determine any variation of effect between low and high performing students. Student GPA was used as an analog for student performance. One of the students who completed the PGS instrument was a non-traditional student, meaning that GPA data was unavailable. This reduced the number of observations to 18 for the regression analysis. A t-test was performed on the calculated regression slope for each subsection against a null hypothesis of 0 slope, providing p-values for comparison. Most of the collected data had weak correlation to GPA. However, the "Grade Motivation" and "Clear Expectations" subsets both had p-values less than 0.10.

The overall PGS score and the number of retakes attempted by students are plotted against student GPA in Figure 1. The "Grade Motivation" and "Clear Expectations" subsets of questions are plotted against student GPA in Figure 2.

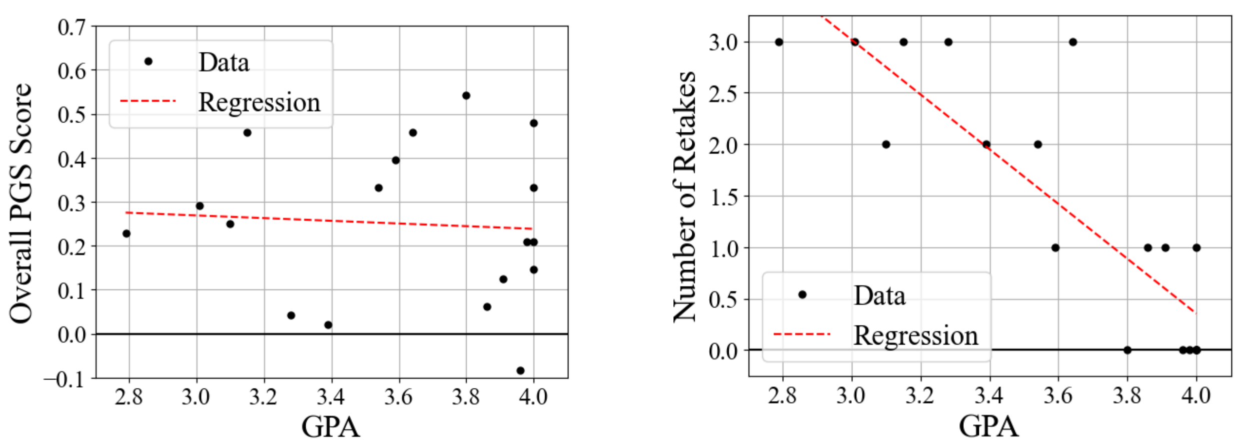

Figure 1. Left - Overall score on PGS instrument vs. Student GPA. Data does not support correlation between overall perception and GPA. Right - Number of Retakes in Fluids vs. Student GPA. Higher GPA is strongly correlated with fewer exam retakes.

The data does not show any clear correlation (p=0.785) between a student's GPA and the overall score given on the PGS assessment, though the Specifications Grading Scheme was almost universally preferred over a Traditional Grading Scheme. There is a very strong negative correlation (p=5.65e-06) between a student's GPA and the number of retakes attempted in the course. Additionally, there is a strong negative correlation (p=0.0214) between a student's GPA and their Grade Motivation Score and a moderate positive correlation (p=0.0653) between student GPA and their understanding of the expectations in the class. Other data did not show evidence of correlation to GPA (p > 0.10).

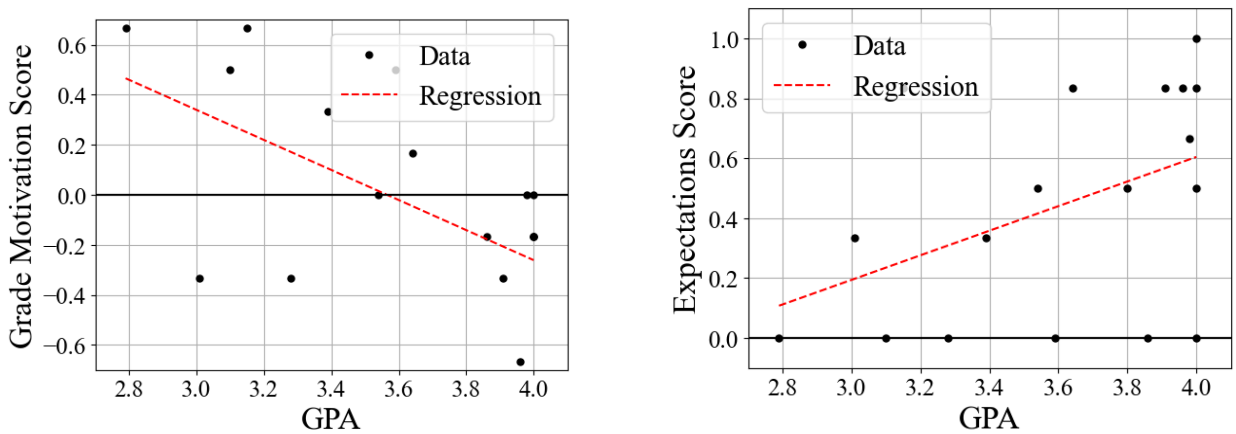

Figure 2. Left - Score on Grade Motivation subsection (Gmt) vs. Student GPA. Higher GPA correlates to lower Grade Motivation Score. Right - Score on Expectations subsection (Exp) vs. Student GPA. Higher GPA correlates to higher Expectations Score.

Course Evaluation Data

Course evaluation data was collected by Abilene Christian, anonymized, then reported to the author. Student responses to the prompts "What did the instructor do that made the course effective?" and "What could the instructor do to improve the effectiveness of this course?" were collected and sorted into appropriate categories.

Reduces Anxiety

- "The grading style was VERY nice, with earning retakes by completing all the homeworks. It helped lower stress but also I still had to learn everything." - Thermodynamics, Spring 2022
- "I really liked how he used the token system for retakes. I like how this system took a lot of pressure off of tests and allowed me to have the opportunity to retake anything that I struggled with." - Thermodynamics, Spring 2025
- "I liked the format of the course, and being able to take retakes takes of lot of stress off of test days." - Fluid Mechanics, Fall 2021

Encourages Use of Feedback

- "I like that this system enables me to actually learn the material and not just get a bad grade on a test and have to move on." - Thermodynamics, Spring 2025
- "One of the things I like about your class structure is retakes, and not just because it's good for my grade but it also provides an extra learning experience/opportunity if I didn't understand enough to do well on the first exam." - Heat and Mass Transfer, Spring 2024

Enhances Understanding of Course Expectations

- "The pedagogical structure is unique and helpful in that the course content remains difficult and challenging while a path for success is well known." - Heat and Mass Transfer, Spring 2020

- “I also like how you explain everything we need to do for each letter grade at the beginning of the semester so that nothing is a surprise.” - Heat and Mass Transfer, Spring 2024

Discussion

Although the sample size of the current study is small, it shows that most of the objectives of the alternative grading scheme used in Fluid Mechanics were achieved from the students’ perspectives. The objectives that did not meet the p=0.05 threshold were “Mot - Promotes motivation to learn”, “Fbk - Useful feedback”, and “Gmt - Promotes motivation to earn higher grades”. Course evaluation responses strongly support that the grading scheme reduces anxiety, encourages the use of feedback through retakes, and enhances the understanding of course objectives.

For motivation, based on the results of Mot3 and Gmt2, it appears that the grading scheme de-emphasizes high performance on individual assignments. This lines up with the requirement of 80% on exams and “Meets Expectations” on projects. However, even combining these two questions, they fail to meet the p=0.05 threshold. More data is needed to provide conclusive evidence one way or the other.

Finally, the “Gmt - Promotes motivation to earn higher grades” is very strongly correlated with student GPA. The grading scheme appears to be strongly motivating for students with low GPAs, while weakly demotivating for students with high GPAs. In other words, lower-performing students are encouraged to spend more time on retakes and attempt the more challenging aspects of the course, with the knowledge that a better grade is possible. The strongest students, however, do not need to put forth their best effort to achieve the maximum grade in the course.

As a final note, student understanding of expectations was moderately correlated with GPA. This indicates that even though the average student felt that expectations were more clear with the specifications grading scheme, the lower-performing students were less likely to feel comfortable with the expectations of the course.

Conclusion

Through the PGS instrument, it was shown that a specifications grading scheme applied to a Junior-level Fluid Mechanics course provided many of the benefits expected from alternative grading schemes. Specifically, students felt less anxious, believed that their grades reflected learning, understood the expectations of the course, and took greater ownership of their grades. In addition, several trends in student responses were noted with relation to student GPA, though most correlations were weak.

Future Work

As an extension of this research, two additional classes (Thermodynamics and Heat and Mass Transfer) are being taught with a similar specifications grading scheme. Data will be collected over the next few years in all three classes, which should allow for better statistical analyses.

References

[1] L. B. Nilson and C. J. Stanny, Specifications grading: restoring rigor, motivating students, and saving faculty time. Sterling, Virginia: Stylus Publishing, 2015

[2] W. J. Howitz, K. J. McKnelly, and R. D. Link, “Delving into the Design and Implementation of Specifications Grading Systems in Higher Education,” Education Sciences, vol. 15, no. 1, p. 83, Jan. 2025, doi: 10.3390/educsci15010083.

[3] Yik, Brandon J., et al. "Students’ perceptions of specifications grading: Development and evaluation of the perceptions of grading schemes (pgs) instrument." Journal of Chemical Education 101.9 (2024): 3723-3738.

Appendix A - Comparison of Grading Schemes

Table A-1. Comparison of Grading Schemes

	Thermodynamics	Fluid Mechanics	Heat and Mass Transfer
Number of Students	Average 26 over 4 years	Average 31 over 5 years	Average 14 over 3 years
Number of Modules/Exams	4 (3-4 weeks each)	5 (3 weeks each)	6 (2-3 weeks each)
Number of Projects	4 (small)	2 (one large, one small)	6 (small)
Module Completion	7 out of 9 points across quizzes/exams	100% on each online quiz (free retakes) 80% on exam	
Specs for 'C'	Modules 1-3 complete		
	Project 1 complete*	Large project complete	Project 2 complete
Specs for 'B'	'C' + 1 "testing criteria", no more than 5 token deficit at end of semester		
	Project 2 complete Choose 1 "add-on"	Choose 2 "add-ons"	Project 5 complete Module 4 complete Choose 1 "add-on"
Specs for 'A'	'C' + 2 "testing criteria", no token deficit at end of semester		
	Project 2 complete Complete all "add-ons"	Choose 2 "add-ons"	Project 5 complete Module 4 complete Choose 2 "add-ons"
List of "add-ons"	Module 4 Project 3 Project 4	Module 4 Module 5 Small project	Module 5 Module 6 Four total projects
List of "testing criteria"	Average 6/9 on first try Average 7/9 on first try Pass Final Exam 75% on Final Exam	Pass 2 exams on first try Pass 4 exams on first try Pass Final Exam 75% on Final Exam	Pass 2 exams on first try Pass 4 exams on first try Pass Final Exam 75% on Final Exam Six total Projects
Token Usage	5 tokens per quiz, exam half or project resubmission	10 tokens per exam or project resubmission	10 tokens per exam, 5 tokens per project resubmission
Token Earning	1 token per homework, video quiz, or online quiz		

*Project "completion" refers to a grade of "Meets Expectations"

Appendix B - Detailed Statistical Analysis

Table B-1. Statistical Analysis of Question Subsets

Question Subset – Grading Scheme…	Mean	Std. Error	95% CI
Out - … reflects student learning outcomes	0.241	0.093	(0.045, 0.436)
Mot - … promotes motivation to learn	0.009	0.097	(-0.195, 0.213)
Anx - … lowers anxiety (negative of "raises anxiety")	0.574	0.103	(0.357, 0.791)
Fbk - … encourages use of feedback	0.167	0.094	(-0.032, 0.366)
Exp - … enhances understanding of course expectations	0.444	0.087	(0.260, 0.629)
Con - … reduces conflict between student and instructor	0.250	0.095	(0.050, 0.450)
Res - … encourages student ownership of grades	0.343	0.067	(0.202, 0.483)
Gmt - … promotes motivation to earn higher grades	-0.028	0.105	(-0.250, 0.195)
Overall PGS	0.287	0.043	(0.197, 0.377)

Table B-2. Statistical Analysis of Mot and Gmt Questions

Question – I am motivated to…	Mean	Std. Error	95% CI
Mot1 - … learn as much course material as possible.	0.139	0.133	(-0.141, 0.419)
Mot2 - … thoroughly understand the course material.	0.083	0.129	(-0.190, 0.356)
Mot3 - … do my best on each assignment.	-0.194	0.108	(-0.422, 0.033)
Gmt1 - … only learn course material that is strictly necessary to earn the grade I want.	0.167	0.167	(-0.185, 0.518)
Gmt2 - … get the highest grade on each assignment.	-0.250	0.163	(-0.594, 0.094)
Gmt3 - … aim for a higher final letter grade.	0.333	0.128	(0.064, 0.603)